THE EFFECTS OF OBSERVATIONS AND MANEUVERS ON ORBIT SOLUTIONS

THESIS

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Abstract

The purpose of this research is to characterize the performance of the optimal sequential filter used in ODTK with a maneuvering satellite. Specifically, this thesis sought to characterize the performance using two scenarios: performance with a maneuver in between passes and performance with a limited number of measurements. The performance of the filter is evaluated by analyzing the covariance values generated during the orbit estimation process. Larger covariance values signify reduced performance of the filter. Several variables for the maneuvering satellite are used, including the maneuver direction and the maneuver magnitude. The time of the maneuver is also varied, which creates a short or long drift time in between passes. Because ODTK derives the satellite state estimate models and state estimate error models from the physics of sensors and force modeling, and it derives all measurement models and measurement error models from the associated hardware definitions and physics, the filter should perform better than other orbit estimation techniques such as Least Squares or a Kalman filter. With sufficient data after a maneuver (about three passes) the ODTK filter is able to provide a good orbit estimate for the satellite. However, without at least three passes to gather new observations, the filter does not perform well.

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Christine M. Schudrowitz

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THE EFFECTS OF OBSERVATIONS AND MANEUVERS ON ORBIT SOLUTIONS

I Introduction

Maintaining Space Situational Awareness (SSA) is a difficult undertaking, and is even harder when satellites maneuver. SSA involves knowing where objects are in orbit around the Earth and predicting where they will be in the future. Orbit determination and prediction are key parts of SSA; when a satellite maneuvers, the determination and prediction are no longer accurate. One must have observations, where a ground station can see the satellite and generate measurements, of the satellite after a maneuver in order to perform the determination and prediction process with any accuracy. Determining how many observations are needed to produce an "accurate" orbit can help operators of a space surveillance network determine when and where to schedule observations to ensure the best use of their network.

1.1 Problem Statement

In order to accurately track a satellite, several observations are needed to build an accurate and predictive orbit solution for that satellite. Several different methods and processes are available to create an orbit solution; however, satellite maneuvers may cause inaccurate ephemeris calculations. The modeling environment provided in the Orbit Determination Tool Kit (ODTK) by Analytical Graphics allows an experimenter to investigate several different scenarios using maneuvers, but a baseline measure of the performance of ODTK is needed. To characterize the performance of the optimal sequential filter used in ODTK, several scenarios with maneuvers were created and

analyzed. The ODTK filter should predict the orbit of the satellite after it maneuvers better than other methods such as Least Squares.

1.2 Motivation

Space is becoming an ever more congested and contested environment. Orbital debris surrounds the Earth, making it difficult to differentiate satellites from debris from a surveillance perspective. Also, due to the congestion of space, satellites are often forced to maneuver to avoid debris. The space surveillance network is aging, and the Joint Space Operations Center (JSpOC) cannot handle the amount of information generated. The next generation of ground sites, the Space Fence, is still in development, and will not be active until 2015 at the earliest. Even if the Space Fence is active, the JSpOC does not have the ability to analyze the amount of data it will generate (Defense Industry Daily: 1). Therefore, knowing how many observations it takes to generate a relatively accurate orbit solution, i.e. how long it takes for the filter to converge, and how that changes given different maneuvers, will help the JSpOC become more efficient at generating valid ephemerides.

1.3 Method of Investigation

Using ODTK, different sets of data were generated by using several variables in the scenario as described in Ch. 3 (the scenario is the base file which objects are added to in order to perform any modeling or analysis). A ground based tracking system and representative satellite is added to the scenario. Simulated observations were generated and run through the optimal sequential filter. To characterize the filter performance a relative convergence definition for the filter is used based on previous research in which

adding observations to the covariance fit reduced the covariances by less than 10% (Johnson: 3-5).

1.4 Document Organization

Chapter 1 of this thesis is the Introduction. Chapter 2 contains a discussion of the Classical Orbital Elements, an overview of observations, and a summary of orbit estimation and determination techniques. A short summary of some of the theorems behind ODTK is provided, as well as a discussion of observable position error after a maneuver to furnish a framework for evaluating some of the covariance results. Chapter 3 discusses the scenario set-up within ODTK, the variables chosen to evaluate the filter results, and the three main cases for investigation. Chapter 4 is an in-depth discussion of all of the results, with some tables and graphs provided for interesting cases. Chapter 5 concludes the thesis with a summary of the filter performance and suggestions for future research.

II Background

2.1 Overview

In order to describe the orbit of a satellite, six independent quantities are needed, such as the Classical Orbital Elements (COEs). Various elements can be used depending on the orbit and type of information available. Once these elements are determined, the orbit of a satellite can be predicted at some future time. However, determining these elements can be difficult based on the type and number of observations of an object. Observations occur during a pass where the ground station can see the satellite; observations are synonymous with measurements. Once measurements are collected, there are numerous ways to process the data in order to predict the satellite's orbit. The Least Squares (LS) method is popular, but it has problems when dealing with a maneuvered satellite. Optimal Orbit Determination (OOD), the method used in ODTK, has some advantages over the LS method. Because ODTK derives the satellite state estimate models and state estimate error models from the physics of sensors and force modeling, and it derives all measurement models and measurement error models from the associated hardware definitions and physics, the filter should perform better than other orbit estimation techniques such as Least Squares or a Kalman filter. In order to characterize the performance of the optimal sequential filter used in ODTK, it is important to understand where and when position errors are observable after a maneuver.

2.2 Classical Orbital Elements

The COEs, or Keplerian elements, are a typical way to describe the orbit of a satellite. The orbit of a satellite can be described by any of four conic sections: a circle,

an ellipse, a parabola, or a hyperbola. To describe a conic section using the two-body equations of motion, six constants of integration are needed. One option is three components of position and three components of velocity. However, the orbit can also be described using five constants and one quantity that varies with time. These quantities are the COEs, described in Table 1 and shown in Figure 1.

Table 1 Classical Orbital Element Descriptions (Larson: 135-137)

Symbol	Name	Description
a	Semi-major axis	Describes the size of the ellipse
e	Eccentricity	Describes the shape of the ellipse. The eccentricity vector points from the center of the Earth to perigee with a magnitude equal to the eccentricity of the orbit.
i	Inclination	The angle between the angular momentum vector and the unit vector in the Z-direction
Ω	Right Ascension of the Ascending Node	The angle from the vernal equinox to the ascending node. The ascending node is the point where the satellite passes through the equatorial plane moving from south to north.
ω	Argument of Perigee	The angle from the ascending node to the eccentricity vector measured in the direction of the satellite's motion.
ν	True Anomaly	The angle from the eccentricity vector to the satellite position vector, measured in the direction of satellite motion.

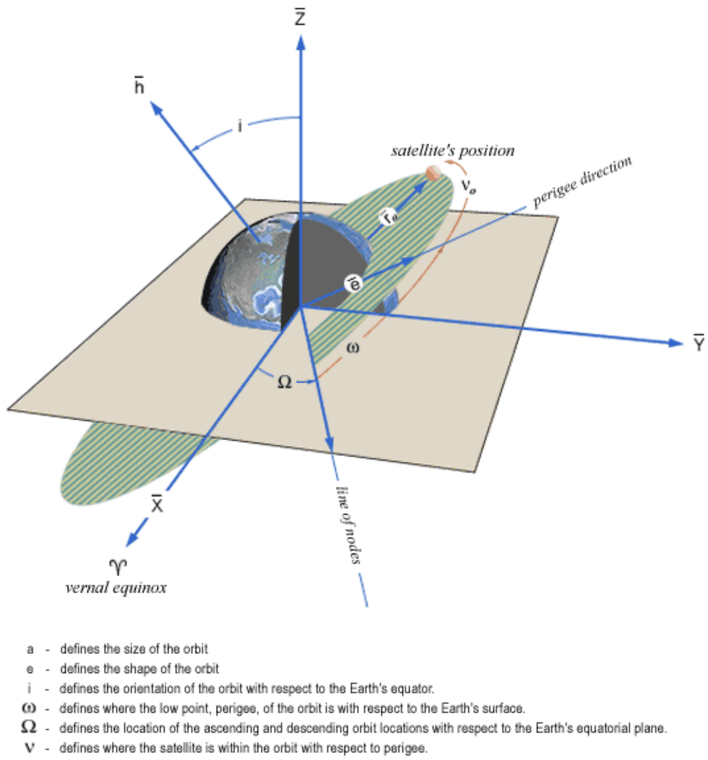

Figure 1 Classical Orbital Element Graphic (Dismukes: 1)

A few other orbit properties are useful in describing the spacecraft motion. The apogee of an orbit is the distance from a focus of the ellipse to the maximum radius of the ellipse. Conversely, perigee is the distance from a focus of the ellipse to the minimum radius of the ellipse. In a circular orbit, apogee and perigee are undefined (Larson: 135-137). The period of an orbit, T, is the time to complete one revolution of the orbit.

2.3 Observations

To predict the ephemeris for a given satellite, observations which produce measurements are needed. Different types of observations provide different data. Typical measurements include range, range rate, azimuth, and elevation. Most ground sites have limiting factors for these measurements. For example, optical sites need an

elevation of 20° to limit atmospheric distortions (Vallado: 242-245). To provide the best observations for orbit estimation, sensors must be spread throughout the world to obtain coverage of a satellite (Vallado: 242-245). The Space Surveillance Network (SSN) uses a combination of phased array radars, conventional radars, electro-optical sensors, and space based space surveillance to gather observations of various types, shown in Figure 2 (USSTRATCOM: 1).

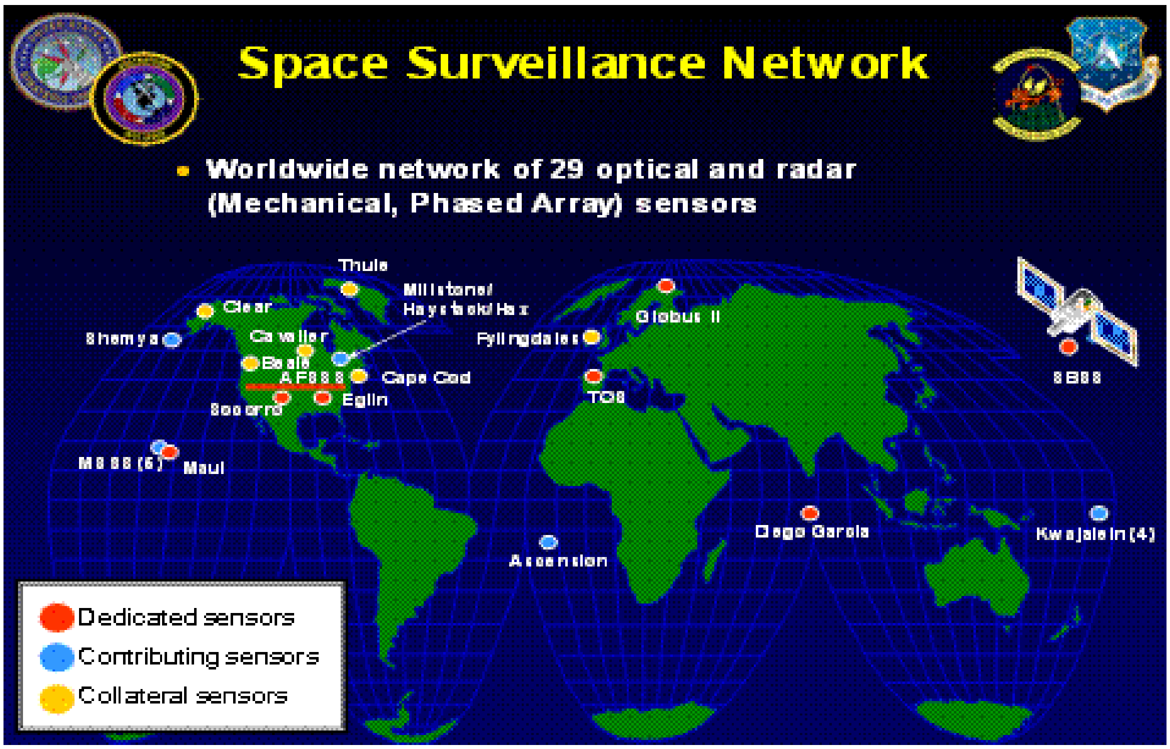

Figure 2 The Space Surveillance Network (USSTRATCOM: 1)

However, the SSN is an aging network. In June 2009, the US Air Force awarded contracts to three major contractors to design the next generation space surveillance system, called the Space Fence. The Space Fence will consist of two to three geographically separated S-band radars (Morales: 1). In January 2011, two contractors

were awarded follow-on contracts to continue development, with initial operational capability scheduled for 2015 (Defense Industry Daily: 1).

Increasing the capacity and capability of the SSN is important because of the number of objects in various orbits (Figure 3). More observations of a given object improve the accuracy of the orbit solution, which could provide advance warning for ground forces or other entities. Also, maneuvering objects create an additional need for observations. Historically, satellites have used maneuvers as station keeping actions, in order to maintain a certain orbit. However, with the additional capability on today's satellites, maneuvers could be used to permanently change a satellite's orbit, or to move the satellite for a purpose other than station keeping. The development of ion propulsion has also created new possibilities; even though the thrust is small, it is continuous. This continuous thrust creates a non-Keplerian orbit, which makes the satellite difficult to track.

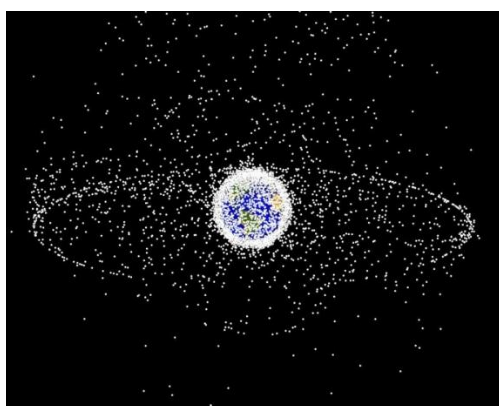

Figure 3 Orbital Debris Density (Orbital Debris: 1)

2.4 Orbit Estimation and Determination

There are numerous methods of orbit estimation. Some common terms used in orbit estimation are predicting, filtering, and smoothing. Predicting uses existing

observations to find future states. Filtering determines the current state by using current and past observations. Smoothing improves state solutions by combining them with future data. Finally, there are two types of estimation: deterministic and stochastic. The deterministic approach assumes everything in the system is accurately modeled; therefore, the only error sources are the measurements themselves. However, when attempting to estimate an orbit, several pieces of the model are not completely known, e.g., atmospheric conditions. The second approach, stochastic, attempts to create a more accurate model by combining information from the dynamics of the system, uncertainties in the force model, and measurement errors to create the best estimate possible. The stochastic approach is generally preferred because its accuracy is better than the deterministic approach (Vallado: 675-678).

The first method of orbit determination was developed by Gauss, and was later termed the Least Squares (LS) method. In the early 1960s, Rudolf Kalman's recursive algorithm for estimation of dynamic systems, a variation of Gauss' LS method, became popular, and is now known as the Kalman filter (Vallado: 675-678). The Kalman filter was designed for generalized filter problems and was not well suited for orbit estimation in its original formulation. However, using adaptive techniques to modify the structure of the filter, variations of the filter have been successfully applied to this problem. There are two ways to implement adaptive techniques: structural and statistical. Statistical techniques, used in Optimal Orbit Determination (OOD), incorporate all known errors into a mathematical model of the process noise, in order to define the process noise as a function of the system's physical processes. (Vallado: 738-739)

There are several problems with the LS method, especially when using real data, not theoretical data. In LS, measurement residuals are treated as white noise. However, when using real data, the measurement residuals are serially correlated, not white. The LS model does not account for serially correlated random gravity model errors, random air-drag modeling errors, and serially correlated random solar pressure modeling errors. In LS, the state error covariance matrix does not include a structure for force modeling errors, only the measurement error covariance. Physically, the effects of force modeling errors and the collection of measurements for the state estimate evolve with time. However, the LS method maps measurement information at distinct times simultaneously to the state estimate. There is no time-sequential structure to encompass force modeling errors. Finally, LS accuracy performance can get worse with more data. LS chooses a state estimate that minimizes the sum of squares of weighted tracking data residuals, instead of minimizing the state error variances (Wright: 271-273).

2.5 Optimal Orbit Determination

This section describes how OOD is different from the LS method. LS can estimate time-varying parameters to a degree, but OOD does a better job. OOD can be used for past, current, and future time, by using a sequential smoother after the filter execution. The smoother provides more accurate trajectory estimates than the filtered trajectory estimates (Wright: 3-4).

The OOD method (calculating the state estimate and orbit estimate) satisfies the following conditions:

1. Sequential processing (processing forward in time with measurements) is used to account for force modeling errors and measurement information in the time order in which they are realized.
2. Sherman's Theorem is applied. To summarize, the optimal state estimate correction matrix $\Delta\hat{X}$ is the expectation of the state error matrix ΔX given the measurement residual matrix Δy. That is: $\Delta\hat{X} = E\{\Delta X|\Delta y\}$.
3. Linearizations of state-estimate time transition and state-to-measurement representations are *local* in time, *not global*.
4. The state estimate structure is *complete*.
5. All state-estimate models and state-estimate-error model approximations are derived from the appropriate *physics* of sensors and force modeling.
6. All measurement models and measurement-error model approximations are derived from the appropriate sensor hardware definitions and associated physics, and measurement sensor performance.
7. Necessary conditions for real data include:
    a. Measurement residuals approximate Gaussian white noise.
    b. McReynold's filter-smoother consistency test is satisfied.
8. For simulated data, the state-estimate errors agree with the state-estimate error covariance function.

The first six conditions define standards for optimal algorithm design and for the establishment of a realistic state-estimate error covariance function. The last two conditions enable validation as they define realizable test criteria for optimality (Wright: 16-17).

2.5.1 OOD Discussion

The following sections (2.5.1 – 2.5.4) from Wright: 17-22 summarize some key points to understand the processes used for OOD. For a complete and thorough discussion of the theorems and algorithms behind OOD, please see reference 12.

The second condition needed for OOD, Sherman's Theorem, allows one to achieve minimum state-estimate error variance, which most directly addresses errors in the orbital elements.

The state estimate structure is almost always incomplete; any component of an observable parameter neglected in the state estimate structure will also show in the estimated orbital elements. There must be a place in the state estimate structure to include every observable effect.

It is important to define Gaussian white noise. Gaussian white noise can be a sequence of ratios from a random walk sequence$R_j, j \in \{0,1,2, \ldots\}$, with the numerator in each ratio as the difference $\left(R_{j+1} - R_j\right)$ in the random walk functional across a specified time interval$\left[t_j, t_{j+1}\right]$. The denominator is the associated time difference$\left(t_{j+1} - t_j\right)$. The ratio limit $\left(t_{j+1} - t_j\right) \to 0$ does not exist. Therefore, Gaussian white noise must always be used in a granular manner.

White noise is very relevant to observations; range and doppler measurements contain Gaussian white noise. Gauss himself used a Gaussian white noise model to represent noise in right ascension and declination.

The Fundamental Theorem of Estimation, with the central limit theorem, supports the use of Gaussian distributions for orbit determination. OOD uses the short version of

the fundamental theorem. Given the state estimate error column matrix δX is Gaussian and the measurement residual column matrix Δy is Gaussian, then the optimal estimator of the state error $\delta\hat{X}$ is the expected value of the state error δX given the measurements of y: $\delta\hat{X} = E\{\delta X|y\}$. The optimal estimator is the conditional mean. Complete hypotheses for the Fundamental Theorem of Estimation are satisfied by many cumulative distributions that are not Gaussian. But since there is little justification for us to consider non-Gaussian distributions for the orbit determination problem, the short version is sufficient.

2.5.2 Optimal Sequential Filter.

The optimal sequential filter repeats a recurring two-step sequence; the first step is a time-update of the state estimate and state covariance (propagating forward), the second step is a measurement-update of the state estimate and state covariance (incorporating the measurement). During the time-update interval, the state estimate error magnitudes increase. Then the measurement update reduces the state estimate error magnitudes. The growth of the error magnitudes is due mostly to errors in force models: gravity, air-drag, solar photon pressure, spacecraft thrusting and outgassing, and thermal re-radiation. The Earth's gravity and air-drag are the largest forces to consider for a Low Earth Orbit satellite. Because the models are based on physical uncertainties, sequential processing accounts for the recursive growth and reduction of the state estimate errors.

2.5.3 Fixed Interval Sequential Smoother.

ODTK uses a fixed interval sequential smoother which uses the outputs from the sequential filter as inputs. The filter outputs are stored for use in the smoother; the last

filter output is used to initialize the smoother. Therefore, the smoother runs backwards with time while the filter runs forward with time. This can be useful for a historical analysis of satellite maneuver(s).

2.5.4 Stochastic Sequences for OOD.

Optimal orbit determination must address at least five classes of physical modeling errors: electronic noise, radio signal phase delay, atmospheric effects on radio signal propagation, imperfect models of natural forces (gravity, drag, etc.), and imperfect models of forces internal to the spacecraft (thrust, outgassing, etc.). Physical modeling errors are stochastic processes, and these processes are sampled with stochastic sequences. See reference 12 for further detail.

2.6 Position Error

Understanding where the greatest position error occurs after a maneuver is important to understand when the error is observable in measurements. If there is a sudden increase in the measurement error, then it is possible a maneuver occurred. If it is possible to perform or schedule observations at a particular point after a maneuver, then it may provide a better orbit solution. The following guidelines should be used, where T is the orbit period (Johnson: 3-5):

1. Intrack maneuvers maximize the position error at ½ T after the maneuver (Figure 4)
2. Crosstrack maneuvers maximize the position error ¼ T and ¾ T after the maneuver (Figure 5)
3. Radial maneuvers maximize the position error at ½ T after the maneuver

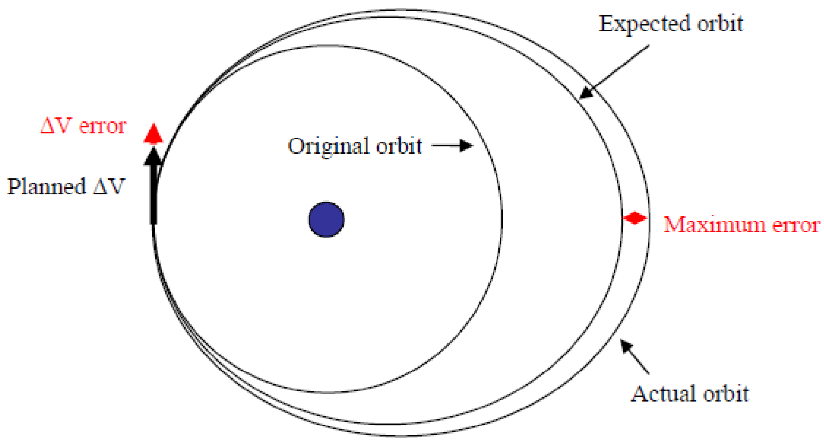

Figure 4 Intrack Maneuver Position Error (Johnson: 4)

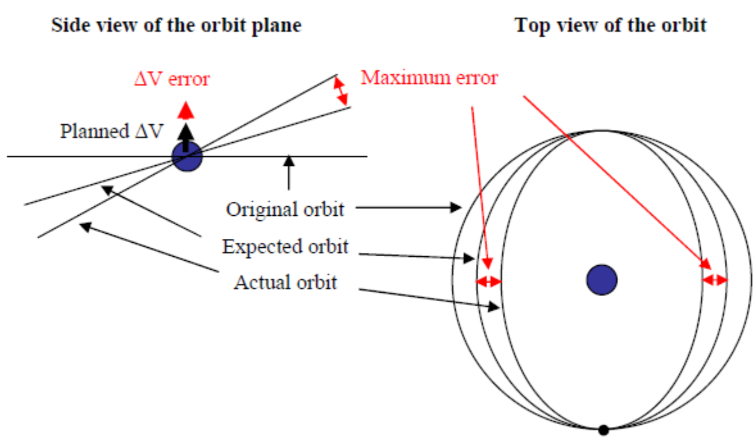

Figure 5 Crosstrack Maneuver Position Error (Johnson: 4)

There are some limitations to the above guidelines. In particular, they only address the magnitude of the position error, not the direction, and errors may be observable at other points in the orbit. How well a particular measurement can observe the error is affected by both of these. The next step is to determine how well the filter performs throughout the orbit, establish how fast it can converge, and what variables affect it (Johnson: 3-5).

2.7 Summary

The number and type of observations after a satellite maneuvers could severely affect the ability of the filter to converge. Because ODTK derives the satellite state estimate models and state estimate error models from the physics of sensors and force modeling, and it derives all measurement models and measurement error models from the associated hardware definitions and physics, the filter should perform better than other orbit estimation techniques such as Least Squares or a Kalman filter. The filter used in ODTK will probably perform better than the Least Squares method or a simple Kalman filter. Where the satellite is located at the time of the maneuver and when the next observations occur may cause more or less error to appear in the filter.

III Model Setup

3.1 Scenario Setup

The scenario uses the projected locations of the Space Fence for the sensor locations, listed in Table 2. These locations are Ascension Island, Kwajalein Atoll, and Western Australia (Defense Industry Daily: 1). Because the performance parameters of the space fence are unknown, a radar sensor is used in order to generate range, azimuth, and elevation data. Each site uses a minimum elevation of 5° and a maximum elevation of 90° as an approximation of sensor limitations. Range, azimuth, and elevation are set as the measurement statistics; the bias model was left at the default of Gauss-Markov for each one. Range includes a white noise sigma of 5 m, azimuth includes a white noise sigma of 0.03°, and elevation includes a white noise sigma of 0.02°. For the scenarios in this thesis, only the Ascension Island site is used, instead of all three, to determine the worst case performance.

Table 2 Sensor Locations (Geodetic Coordinates) (Payte: 38)

Sensor Site	Latitude	Longitude	Altitude
Ascension Island	7.9° S	14.4° W	0
Kwajalein Atoll	9.2° N	167.4° E	0
Western Australia	32° S	115.9° E	0

The satellite properties are 400 kg dry mass with 87 kg wet mass, for a total mass of 487 kg to model a small satellite, such as ORS-1 (Butler: 1). The defaults in ODTK, such as the force model, which included gravity, drag, solar pressure, and central body radiation, are left as is. Maneuvers are done in the Radial, Intrack, Crosstrack (RIC)

coordinate frame, shown in Figure 7. The maneuver estimation option in the filter is set to “false.” The initial satellite properties are shown in Table 3:

Table 3 Initial Satellite Properties

Property	Value
Coordinate Frame	ICRF
Semi-major Axis	6878.137 km
Eccentricity	0
True Argument of Latitude	0°
Inclination	45°
Right Ascension of the Ascending Node	0°
Argument of Perigee	0°

Filter convergence is defined in a relative sense using a threshold of 10% for the uncertainty after the first measurement in the pass (the time update, σ_T) and the uncertainty after the measurement update has been performed (σ_M) (Johnson: 2). The filter process calculates these values during each pass.

$$\frac{|\sigma_M - \sigma_T|}{\sigma_T} < 10\% \qquad \textbf{(1)}$$

The uncertainty is calculated in the covariance matrix. The covariance matrix is the estimate of the fit with the chosen model; it contains the variances and covariances. The uncertainty is a 1σ standard deviation which gives the statistical accuracy of the state in the satellite coordinate frame (Vallado: 690-691). The initial orbit uncertainties for the satellite are left at the default values, shown below in Table 4.

Table 4 Initial Orbit Uncertainties

Property	Value	Units
R_sigma	50	m
I_sigma	100	m
C_sigma	20	m
Rdot_sigma	0.06	m/s^2
Idot_sigma	0.04	m/s^2
Cdot_sigma	0.02	m/s^2

To characterize the performance of the filter, the position, velocity, and orbital element uncertainties for each pass are tabulated and compared. Cases are compared against each other to determine which variables or maneuvers have an effect on filter performance.

3.2 Cases

Several variables are used in order to characterize the performance of the OOD filter in various situations, listed in Table 5. Appendix A provides the complete list of cases.

Table 5 Variable Types/Values

Variable	Type/Value
Number of Measurements	Range Azimuth Elevation
Maneuver Direction	Radial Intrack Crosstrack
Maneuver Magnitude	1 m/s 5 m/s 10 m/s
Drift Time	<10 hrs >10 hrs
Maneuver Magnitude Uncertainty	1%
Maneuver Direction Uncertainty (1σ)	0.1°
Orbit Regime	LEO circular inclined LEO elliptical

The number of measurements should have a large effect on the orbit solution, reflected in the covariance matrix values for position and velocity (uncertainty values). For example, the sigma values for position create an uncertainty bubble around the satellite, with a value associated with each direction of the coordinate frame for the satellite. The bubble is generally larger in the intrack direction and smaller for the crosstrack and radial position, so the bubble ends up shaped like a rugby ball around the satellite, shown in Figure 6. The uncertainty bubble should be smaller with more measurements, and larger with fewer measurements. The goal of choosing the number of measurements as a variable is to determine how many measurements are really needed to define a "good enough" orbit solution. This may help operators determine how many measurements during a pass are needed, in order to efficiently use the sensor.

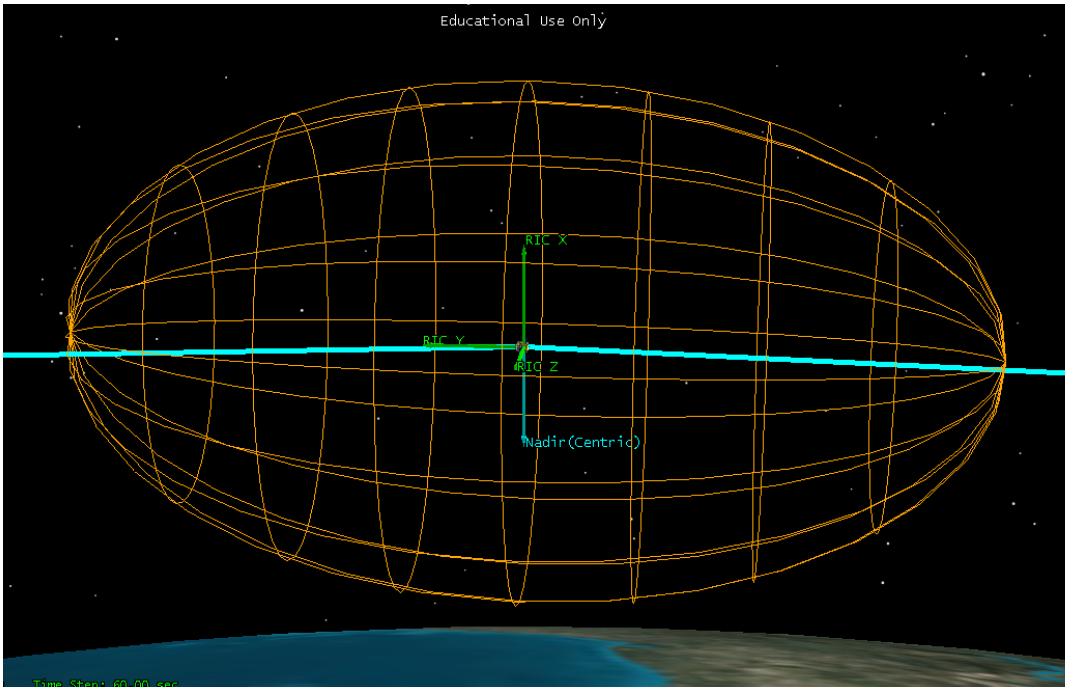

Figure 6 Example Covariance Bubble (Rugby Ball)

For maneuver direction, larger uncertainties are expected for radial and intrack maneuvers versus crosstrack maneuvers, since crosstrack maneuvers require a large ΔV in order to affect an inclination change to the orbit. As the ΔV increases, the uncertainty is expected to increase; small uncertainty increases are expected for a 1 m/s maneuver. Drift time between passes is used to define how much drift time between passes might affect the filter convergence time. Finally, maneuver magnitude and direction uncertainty were added to the simulation, since perfect knowledge of magnitude and direction is highly unlikely in a real world scenario.

Maneuvers are done in succession through the RIC coordinate frame, shown in Figure 7.

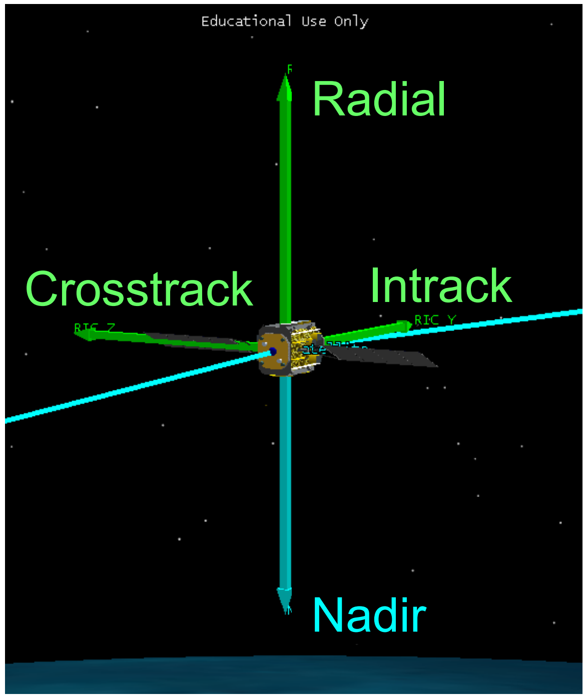

Figure 7 RIC Coordinate Frame (green arrows)

For example, Case 1a has a maneuver in the radial direction. Case 1b has the maneuver in the intrack direction, and Case 1c has the maneuver in the crosstrack direction. This pattern is followed for all case variants. After changing the maneuver direction, the magnitude of the maneuver is changed. For example, Case 1d is a radial maneuver at 17:35 (the same time as Case 1a) but the magnitude is increased to 5 m/s. Then the next set of cases (1g, 1h, and 1i) increase the maneuver magnitude to 10 m/s. Finally, the time of the maneuver is changed, and cases completed following the above pattern (changing maneuver direction, and then increasing maneuver magnitude). The time of the maneuver relative to each pass is shown in Figure 8.

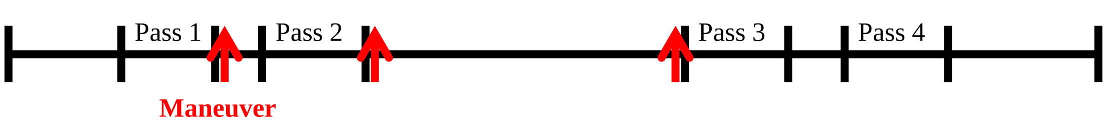

Figure 8 Maneuver Time Relative to Each Pass

3.2.1 Base Case and Case 1 Description

In order to compare filter convergence without a maneuver and with a maneuver, a base scenario with the Ascension Island sensor and one satellite with a total duration of 24 hours were created. The simulator time step is set to one minute, which allows measurements to be taken every minute during a pass over the sensor site. There are a total of four passes, starting from 1 July 2011 12:00:00 to 2 July 2011 12:00:00. The only measurements taken are range, azimuth, and elevation. The number of measurements column in Table 6 reflects the total of all three types of measurements for the Base Case and all Case 1 variants. For example, if there are 15 measurements, then there are five measurements of range, five measurements of azimuth, and five measurements of elevation. The actual pass times and number of measurements may vary slightly based on the type of maneuver performed.

Table 6 Case 1 (i = 45°) Pass Summary

	Start Time	Stop Time	Number of Measurements
Pass 1	01 Jul 2011 17:27	01 Jul 2011 17:32	18
Pass 2	01 Jul 2011 19:04	01 Jul 2011 19:13	27
Pass 3	02 Jul 2011 05:07	02 Jul 2011 05:15	30
Pass 4	02 Jul 2011 06:48	02 Jul 2011 06:52	15

In order to provide a quick comparison to the LS method, the same properties for the Base Case are used to run LS in ODTK. The results from the LS method should be less accurate than the results from the filter; see the discussion provided in Sections 2.3 and 2.4. Finally, the Base Case is also run with the fixed interval sequential smoother to demonstrate the improvement it provides.

3.2.2 Case 2 Description

Case 2 uses the same satellite properties as Case 1, except the inclination is changed to 90°. After analysis of the Case 1 variants, the 1 m/s maneuver is not used for Case 2 variants because it does not significantly affect the results. The position covariance increase is on the order of meters with the 1 m/s maneuver. Because of the slight change in time for the first pass due to the change in inclination, the first maneuver is adjusted to occur at 17:40 instead of 17:35. The slight time change for the maneuver does not significantly affect the error determination analysis performed for Case 1 variants (see Section 3.2.4). Table 7 shows the pass summary for all Case 2 variants.

Table 7 Case 2 (i = 90°) Pass Summary

	Start Time	Stop Time	Number of Measurements
Pass 1	01 Jul 2011 17:30	01 Jul 2011 17:36	21
Pass 2	01 Jul 2011 19:04	01 Jul 2011 19:10	21
Pass 3	02 Jul 2011 05:16	02 Jul 2011 05:20	15
Pass 4	02 Jul 2011 06:49	02 Jul 2011 06:56	24

3.2.3 Case 3 Description

Case 3 repeated the Case 1 variants, except the 1 m/s maneuvers. Case 3 reduced the number of measurements approximately 50%, shown in Table 8, in order to determine if reducing the measurements have an effect on the filter performance. The measurements are reduced by halving the total pass time; for example if the pass is from 17:30 to 17:41, then the time interval option is used to end the pass at 17:36 instead of 17:41. Larger covariance bubbles are expected.

Table 8 Case 3a (i = 45°, reduced measurements) Pass Summary

	Start Time	Stop Time	Number of Measurements
Pass 1	01 Jul 2011 17:30	01 Jul 2011 17:36	9
Pass 2	01 Jul 2011 19:04	01 Jul 2011 19:10	15
Pass 3	02 Jul 2011 05:16	02 Jul 2011 05:20	15
Pass 4	02 Jul 2011 06:49	02 Jul 2011 06:56	9

The error analysis performed for Case 1 variants also applies to the Case 3 variants. Greater uncertainty is expected since there were fewer measurements.

3.2.4 Position Error Analysis

A radial or intrack maneuver will create the most error in orbit prediction at ½T (Johnson: 4). The approximate period for all Case 1 variants is 94 minutes. Therefore, with the maneuver performed at 17:35, the greatest error magnitude is at 18:22. The satellite almost completes its orbit by the time of the next pass at 19:05. Therefore it should be more difficult for the filter to converge because in essence there is no way to detect the error from the maneuver for the chosen measurement set (range, azimuth, and elevation). Continuing to use the period of 94 minutes, the next T=0 point near a pass is at 04:33 on 2 July. The next pass at 05:10 is approximately 37 minutes later, which puts it in a good position to detect the error from the radial and intrack maneuvers. The final pass at 06:51 is in the best position, since it is at approximately 44 minutes from T=0. So, the filter should converge by the fourth pass for all intrack and radial maneuvers.

A crosstrack maneuver will create the most error at ¼T and ¾T after the maneuver (Johnson: 4). For a maneuver at 17:35, ¼T is at approximately 17:58:30, and ¾T is at 18:45:30. So, the second pass at 19:05 is not in a good position to detect the error from a crosstrack maneuver. Based on the analysis for the intrack/radial

maneuvers, the last two passes are in bad positions to detect any error from a crosstrack maneuver (since they are closer to ½T). However, crosstrack maneuvers are very expensive relative to their ability to change an orbit. Therefore, the only maneuver that may create some crosstrack error is the 10 m/s maneuver. So, Cases 1a-1f should have little error from the crosstrack maneuver.

3.3 Summary

The model is now completed within the ODTK scenario, with one ground station at Ascension Island and one satellite in a circular, LEO orbit. A convergence criterion is defined to provide a metric for the evaluation of the filter performance. Maneuver magnitude and direction are varied with three different orbits to create a total of 66 individual cases. Case 1 uses the satellite in an orbit with a 45° inclination, Case 2 uses the satellite in a 90° inclination, and Case 3 uses the satellite in a 45° inclination but only uses half of the available measurements. The position error analysis is used to determine whether each pass after a maneuver will detect the error generated from the maneuver. Chapter 4 describes the results of each case.

IV Results

4.1 Overview

The graphs and tables included in the following sections show the results of the various test cases described in Chapter 3. Graphs and tables are shown for the Base Case and other cases to determine the effectiveness of the filter in overcoming the error generated by satellite maneuvers. Measurement residuals are included in Appendix B, and all other tables with individual case results are located in Appendix C if they are not already included in the text. All results use 2σ (95% confidence); for the position this describes the covariance bubble. is used to determine the relative convergence percentage, with 10% as the threshold. As seen in the magnitude tables (Table 10 and Table 12), there are two lines with the same time stamp. The first line is the time update for the filter (σ_T); the second line is the measurement update through the filter (σ_M).

4.2 Base Case Results

The Base Case provides a reference point for analysis. For the Base Case, there is no maneuver and uses Table 3 for the satellite properties. Uncertainty for the intrack position is expected, since intrack is the most sensitive direction to determine and measure. The uncertainty is still reduced to about 20 meters (m) by the fourth pass, which significantly reduced the initial intrack uncertainty of 100 m. Radial velocity is also difficult to track, but by the fourth pass the uncertainty is very small, about 10 cm/s. All other position and velocity uncertainties are well within the 10% convergence threshold (Table 9-12).

The semi-major axis uncertainty in Table 11 does not meet the threshold for convergence; however the actual magnitude of the uncertainty in Table 12 is very small, about 6 m. The uncertainties for the other orbital elements are very small; the true argument of latitude does not meet the threshold for convergence, however, as with the semi-major axis, the actual magnitude of the uncertainty is very small. Note there are two lines with the same time stamp for the magnitude tables; as discussed in the overview, the first line is the time update for the filter (σ_T) and the second line is the measurement update through the filter (σ_M).

Table 9 Base Case (*i* = 45°) Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
Pass 1	85.05	97.49	1.51	96.16	77.79	0.50
Pass 2	15.34	63.51	0.18	57.59	8.67	0.08
Pass 3	38.75	90.83	0.46	88.05	32.96	0.00
Pass 4	4.09	17.30	5.22	15.36	2.31	0.04

Table 10 Base Case (*i* = 45°) Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	**Radial**	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
01 Jul 2011 17:27:00	208.138	4,008.644	21.898	446.39	16.54	2.22
01 Jul 2011 17:27:00	31.120	100.766	21.567	17.15	3.67	2.21
01 Jul 2011 19:05:00	34.747	141.601	20.552	27.16	3.58	2.26
01 Jul 2011 19:05:00	29.418	51.670	20.515	11.52	3.27	2.26
02 Jul 2011 05:10:00	50.736	609.231	23.513	64.64	5.38	2.50
02 Jul 2011 05:10:00	31.075	55.881	23.406	7.72	3.61	2.50
02 Jul 2011 06:51:00	22.814	70.714	22.935	11.69	2.51	2.60
02 Jul 2011 06:51:00	21.880	58.477	21.739	9.89	2.45	2.59

Table 11 Base Case (i = 45°) Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	89.99	64.36	97.59	0.16	1.79	0.85
Pass 2	49.88	3.51	59.82	0.08	0.18	39.21
Pass 3	43.94	14.20	90.37	0.14	0.34	27.73
Pass 4	12.92	5.78	10.50	0.19	5.10	5.40

Table 12 Base Case (i = 45°) Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013412	0.033488613	0.000165702	0.000259547	0.524039
01 Jul 2011 17:27:00	12.09	0.000004779	0.000806592	0.000165440	0.000254910	0.519572
01 Jul 2011 19:05:00	12.41	0.000004495	0.001190234	0.000169822	0.000242609	0.504855
01 Jul 2011 19:05:00	6.22	0.000004337	0.000478277	0.000169686	0.000242164	0.306901
02 Jul 2011 05:10:00	10.73	0.000006415	0.005094589	0.000192863	0.000270273	0.587256
02 Jul 2011 05:10:00	6.02	0.000005504	0.000490441	0.000192601	0.000269347	0.424411
02 Jul 2011 06:51:00	6.61	0.000006305	0.000612436	0.000196157	0.000269054	0.898091
02 Jul 2011 06:51:00	5.76	0.000005941	0.000548151	0.000195791	0.000255334	0.849603

The measurement residuals for the Base Case provide a reference point to compare with the residuals from the maneuver cases. Due to the scales involved, Figure 9 shows the residuals from the second pass and Figure 10 shows the residuals from the third pass. All of the residuals are within the 3σ bound, which indicates the filter did not reject any of the measurements. Also, these residuals are small, which indicates the difference between the model and truth is about 50 m at the largest. This means the satellite is close to where the filter thinks the satellite is located. If the residuals are very large, then the covariance values from the filter could be very small, but the satellite

would actually be in a completely different location. Data tables with the residuals from each pass are included in Appendix B.

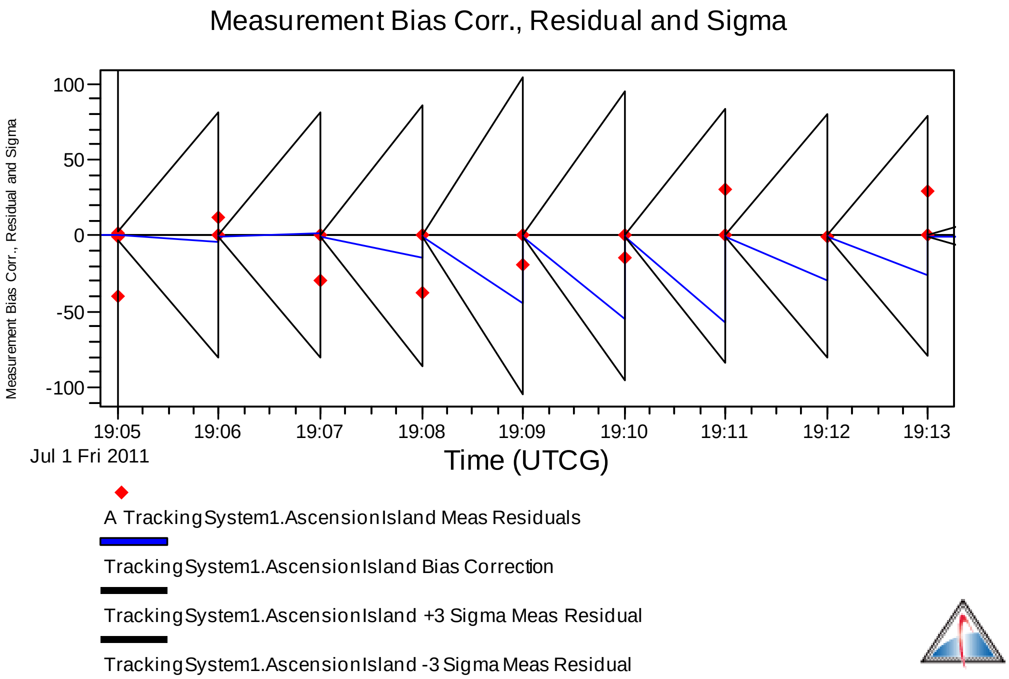

Figure 9 Measurement Residuals, 2nd Pass, Base Case

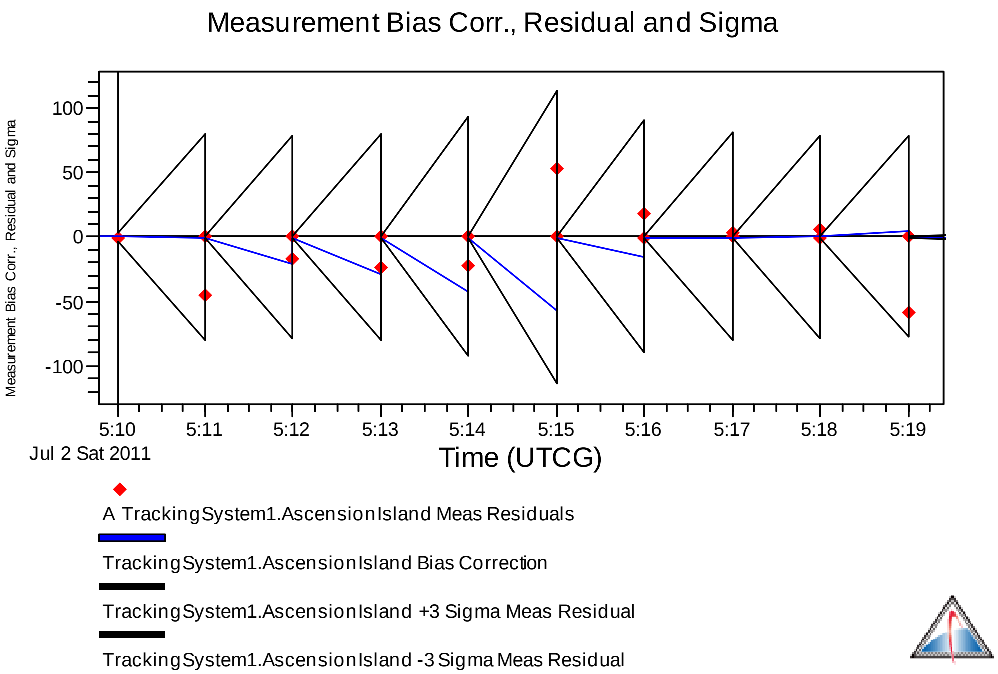

Figure 10 Measurement Residuals, 3rd Pass, Base Case

The following graphs, for the Base Case with no maneuver, provide a visual representation of the changing uncertainties for the position, velocity, semi-major axis, and eccentricity. Note the discontinuities occur when there is a pass and measurements are taken. The oscillation in the position and velocity uncertainty reflect the true anomaly of the satellite (Figure 11 and Figure 12). The troughs should reflect the true anomaly at the time of the pass, where it is most accurate. The uncertainty increases as the satellite continues around the earth, hitting the maximum 180° from the ground station. The growth of uncertainty magnitudes is mostly due to uncertainties in force models: gravity, air-drag, solar photon pressure, etc. (Wright: 31). The large increase of the intrack uncertainty between the simulation start at 12:00 and the first pass at 17:27 occurs because of the initial uncertainty included in the simulation and the uncertainties in the force models, which cannot be reduced until the observations from the first pass.

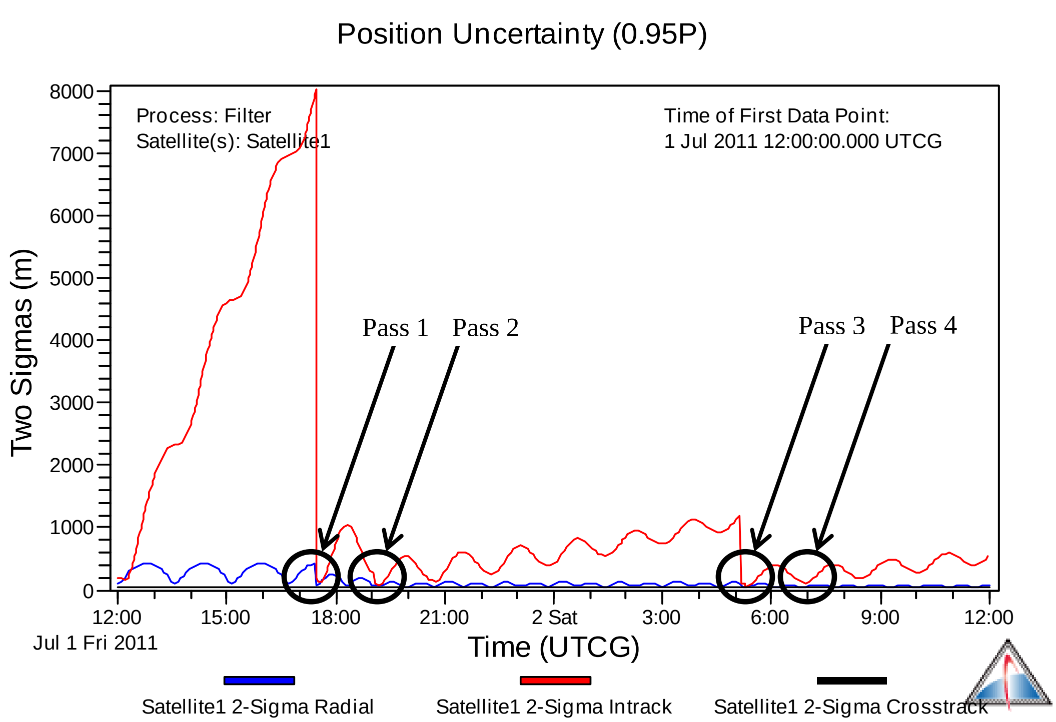

Figure 11 Base Case (*i* = 45°) Position Uncertainties

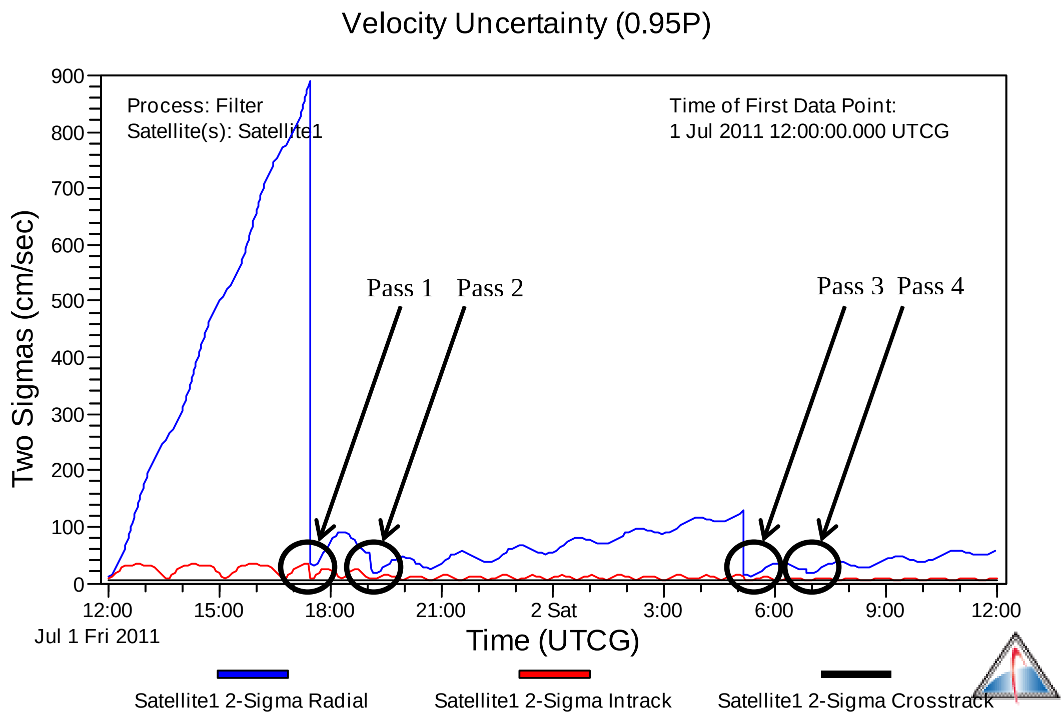

Figure 12 Base Case (*i* = 45°) Velocity Uncertainties

Note the two different scales for the semi-major axis and the eccentricity (Figure 13). The eccentricity appears to have a huge variation; however it is on the order of 10^{-5}. The semi-major axis uncertainty settles to a few meters by the fourth pass.

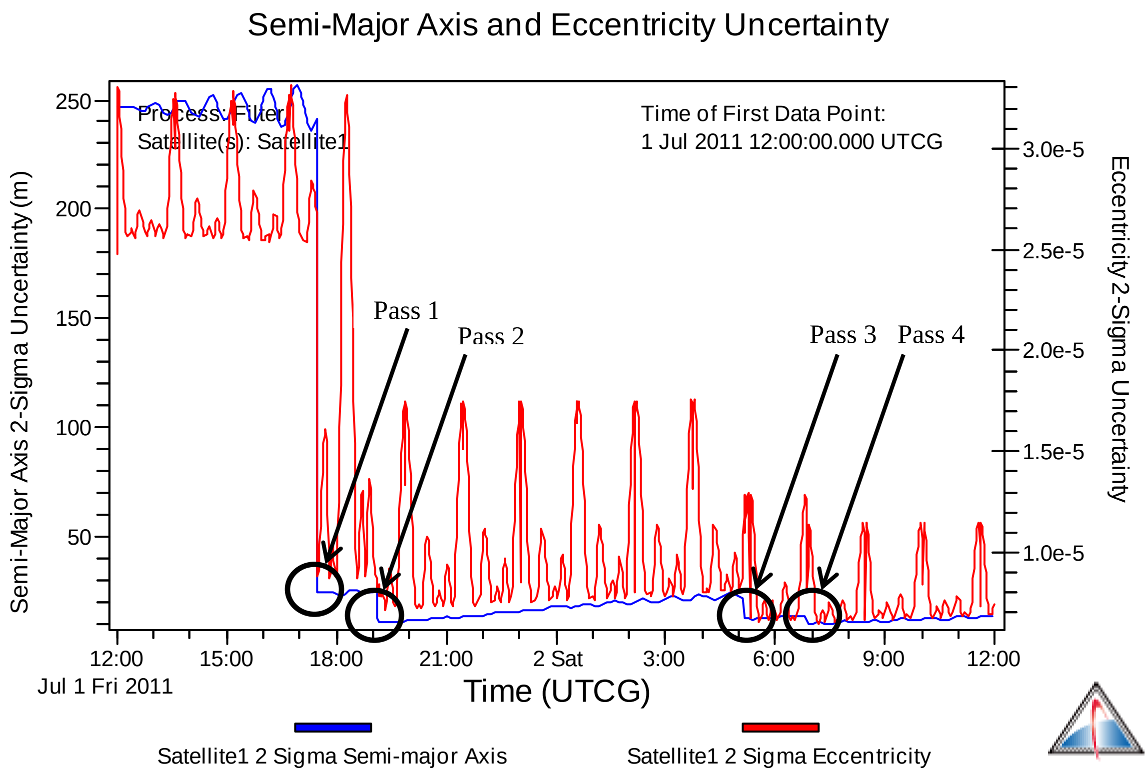

Figure 13 Base Case (*i* = 45°) Semi-Major Axis and Eccentricity Uncertainties

4.2.1 LS Results with the Base Case

The results from the LS method are not very good. Table 13 shows the differences for the position and velocity of the satellite, using the simulator output (truth) and the LS output for the first two passes. The output is in the Earth centered International Celestial Reference Frame (ICRF), with Cartesian coordinates (not the RIC frame).

Table 13 LS State Estimate Differenced with Simulator State (Truth)

	Position (m)			Velocity (m/s)		
Time	**X**	**Y**	**Z**	**$\dot{X}$**	**$\dot{Y}$**	**$\dot{Z}$**
01 Jul 2011 17:35:00	3927	12888	49165	20.8	88.0	74.2
01 Jul 2011 19:15:00	2976	57396	35339	0.0973	106	94.4

4.2.2 Smoother Results with the Base Case

The smoother, due to post-processing, provides very good results for all passes, instead of just the last pass, shown in Table 14.

Table 14 Base Case with Smoother Pos/Vel Uncertainties

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	**Radial**	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
01 Jul 2011 17:27:00	21.020	31.061	17.475	4.50	2.38	2.07
01 Jul 2011 19:05:00	19.834	25.854	17.526	5.02	2.22	2.11
02 Jul 2011 05:10:00	24.111	26.589	19.658	4.71	2.81	2.19
02 Jul 2011 06:51:00	20.567	45.662	19.119	8.14	2.31	2.29

Figure 14 and Figure 15 provide a visual representation of the position and velocity uncertainties, improving from the last pass to the first pass. Note the largest position uncertainty is about 575 m, instead of about 8000 m for the filter. The largest velocity uncertainty is about 58 cm/s versus 875 cm/s for the filter. If a maneuver was included, the smoother can assist with a historical analysis of the maneuver, and may provide better data for maneuver prediction.

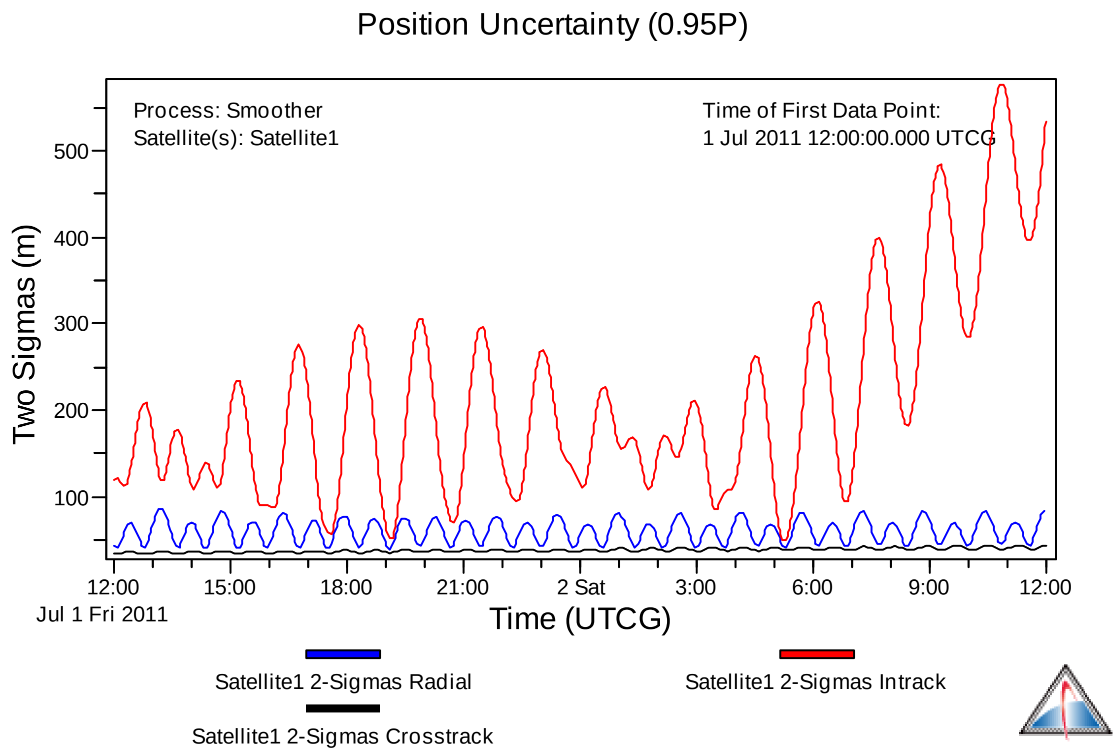

Figure 14 Base Case with Smoother Position Uncertainties

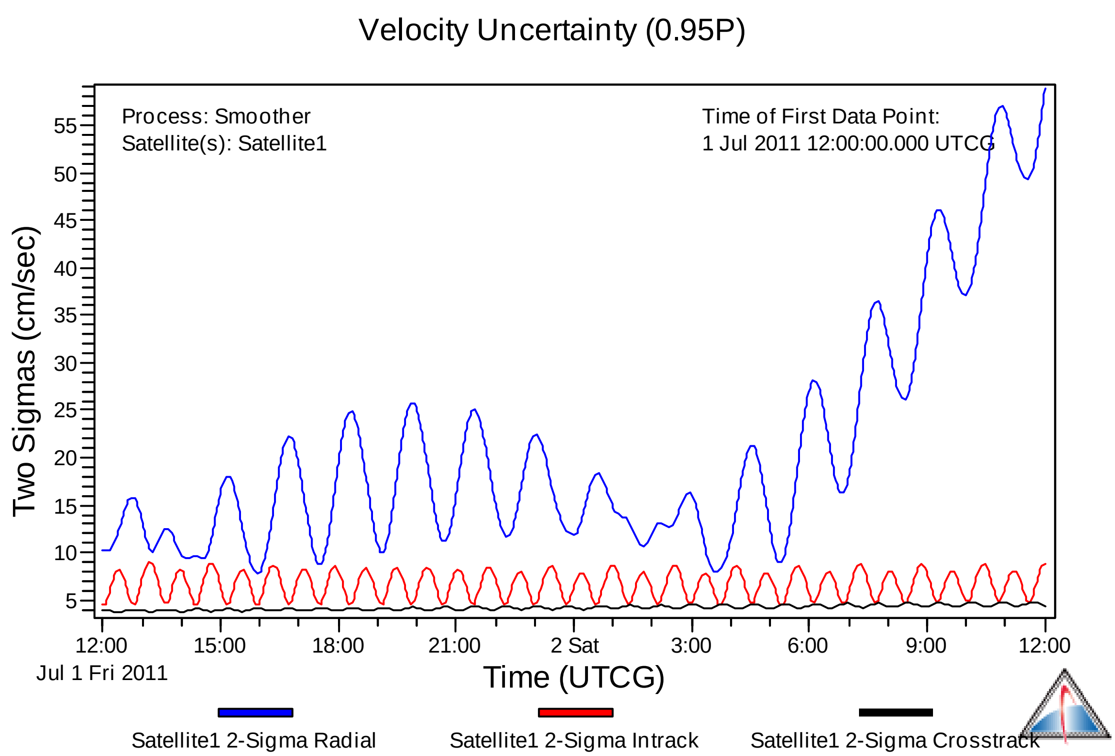

Figure 15 Base Case with Smoother Velocity Uncertainties

4.3 Case 1 Variants

All Case 1 variants use the initial satellite properties from Table 3. The following subsections are broken down by the time of the maneuver, starting with the maneuver directly after the first pass, then directly after the second pass, and finally directly before the third pass.

4.3.1 Cases 1a-1i, Maneuver at 17:35

Cases 1a-1i include a maneuver directly after the first pass, at 17:35. A maneuver at 17:35 creates a short drift time, approximately 90 minutes, before the next pass at 19:05.

Cases 1a-1c use a 1 m/s maneuver at 17:35. As expected, the uncertainty percentages closely match the Base Case. The intrack maneuver (Case 1b) has a slightly higher intrack sigma magnitude, expected since it is an intrack maneuver, shown in Figure 16. The blue line in the figure shows the time of the maneuver. The uncertainty growth should be similar to the Base Case, but not exactly the same, due to the maneuver.

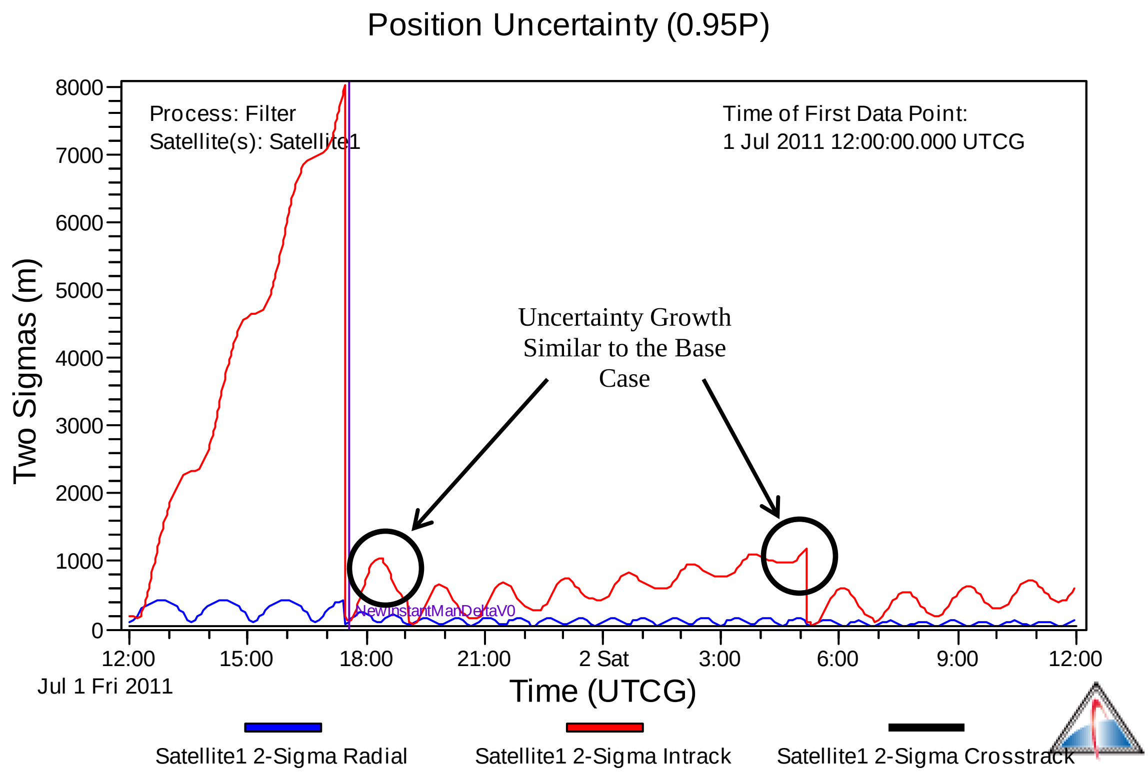

Figure 16 Intrack Maneuver, 1 m/s, *i* = 45° (Case 1b) Position Uncertainties

The measurement residuals for Case 1b are slightly worse than the Base Case for the second pass, which makes sense considering the small maneuver, shown in Figure 17. The range residual at the beginning of the second pass increased from 40 m in the Base Case to 47 m with the 1 m/s intrack maneuver. The range residual shows an increase of about 150 m at the start of the third pass, and an increase of about 30 m at the start of the fourth pass compared to the Base Case residuals. However, by the second measurement in a given pass, the residual is significantly reduced, and is generally only a few meters in magnitude. This means the model is very close to truth. Which in turn means the satellite is very close to where the filter thinks it is within the position and velocity covariance values.

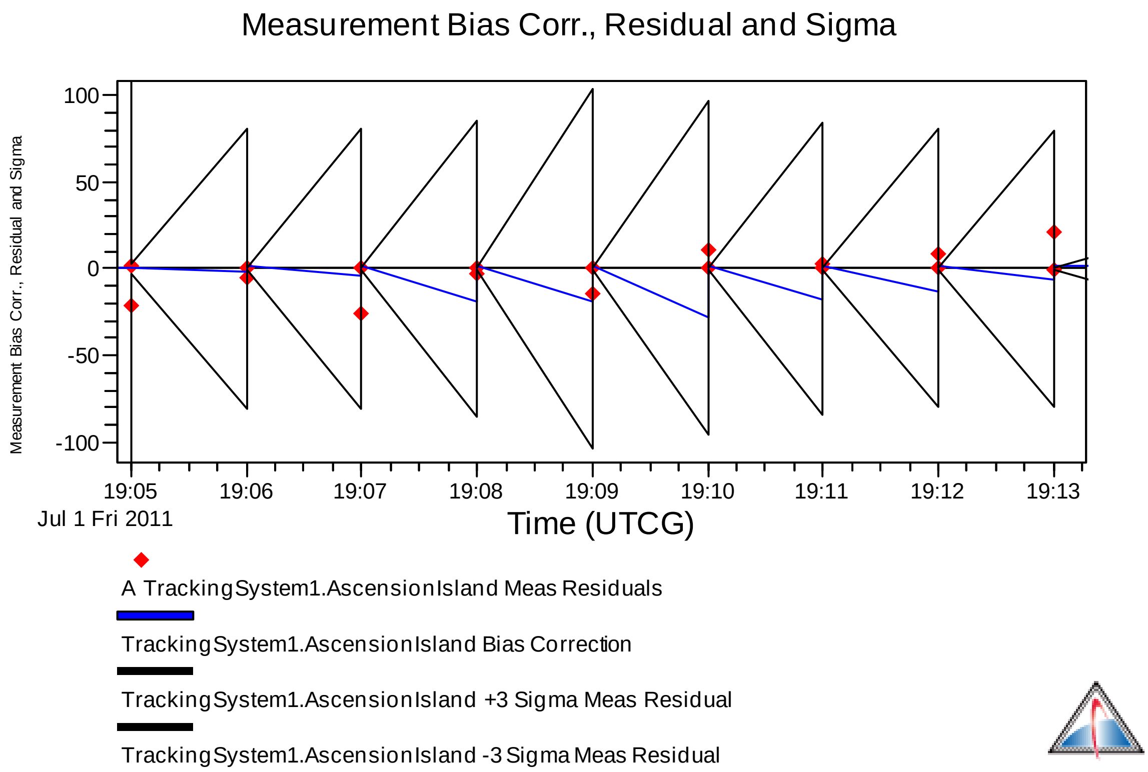

Figure 17 Intrack Maneuver, 1 m/s, *i* = 45° (Case 1b) Measurement Residuals, 2nd Pass

Cases 1d-1f use a 5 m/s maneuver at 17:35. The intrack maneuver (Case 1e) causes the greatest uncertainty in the eccentricity. The radial (Case 1d) and crosstrack (Case 1f) maneuvers cause the greatest uncertainty in the intrack position. As expected the crosstrack maneuver causes the greatest uncertainty for inclination, but it is still within the convergence threshold. Otherwise the filter converges for all elements except the intrack position and the radial velocity, shown in Figure 18.

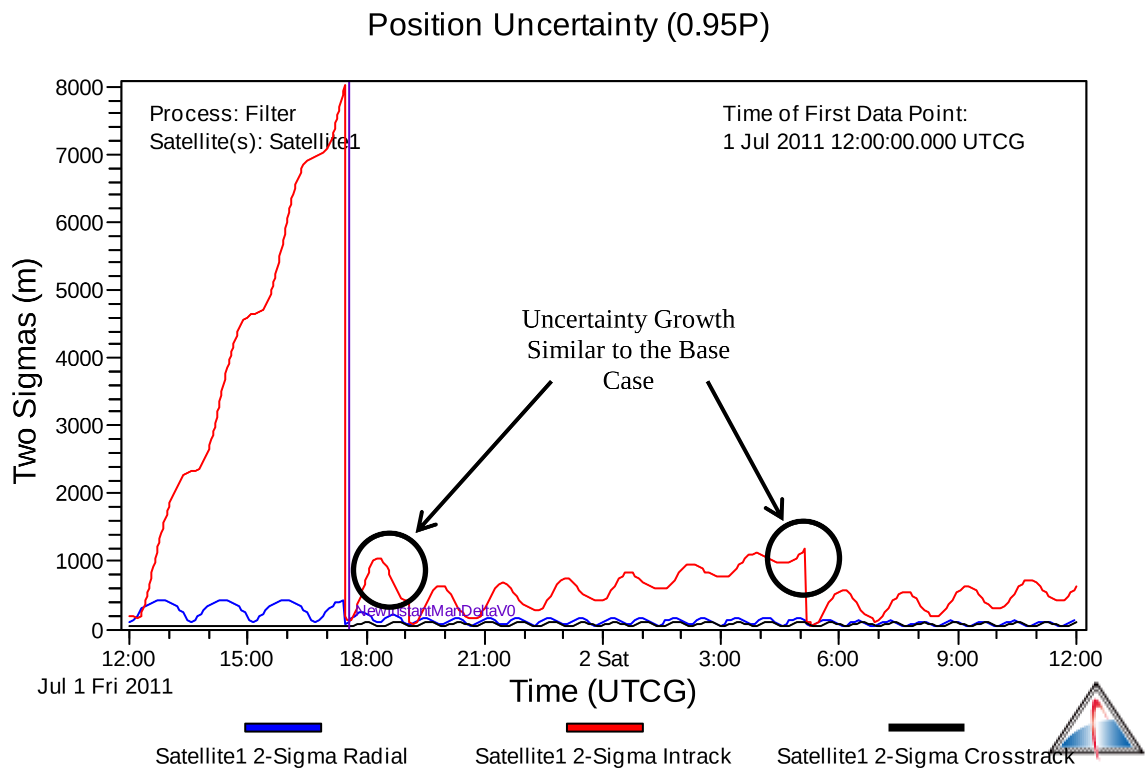

Figure 18 Crosstrack Maneuver, 5 m/s, *i* = 45° (Case 1f) Position Uncertainties

The measurement residuals for the 5 m/s intrack maneuver (Case 1e) show a large increase in the range residual, about 275 m, compared to the 1 m/s intrack maneuver at the beginning of the second pass (Figure 19). However by the end of the second pass the range residual is on par with the range residual from the 1 m/s intrack maneuver. The range residuals from the third and fourth passes are similar for the 5 m/s maneuver and the 1 m/s maneuver. Again, the model is close to truth.

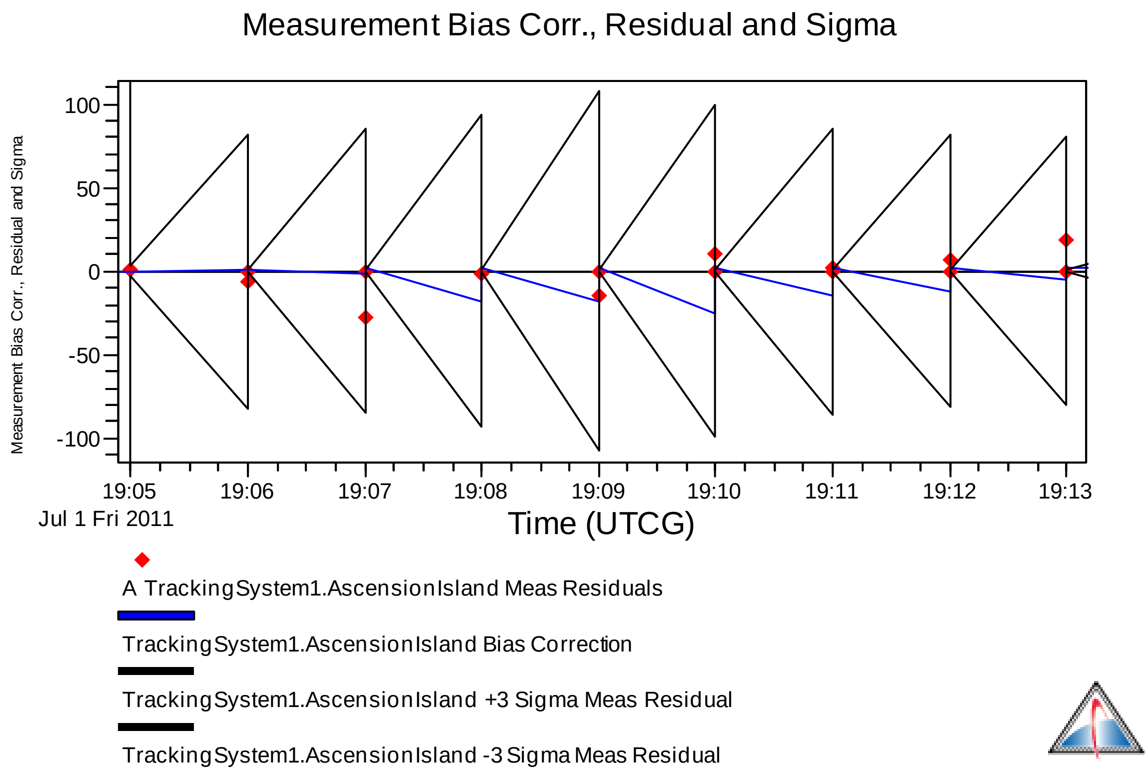

Figure 19 Intrack Maneuver, 5 m/s, *i* = 45° (Case 1e) Measurement Residuals, 2nd Pass

Cases 1g-1i have a 10 m/s maneuver at 1735. As expected, the uncertainties are large for the radial and intrack elements until the fourth pass. The crosstrack maneuver (Case 1i) causes the largest amount of uncertainties compared to the other 10 m/s maneuver cases, creating a relatively large crosstrack velocity uncertainty highlighted in Table 15 (7.8 cm/s vs. 2.8 cm/s for Case 1g and Case 1h). However, most of the filter results are not far from the Base Case, demonstrating its ability to converge even with a large maneuver, provided there are sufficient observations after the maneuver (Figure 20).

Table 15 Crosstrack Maneuver, 10 m/s, *i* = 45° (Case 1i) Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.464	333.462	32.834	42.39	3.88	9.81
01 Jul 2011 19:05:00	33.031	57.705	32.824	13.36	3.81	9.81
02 Jul 2011 05:10:00	56.630	610.083	73.379	64.70	6.14	6.76
02 Jul 2011 05:10:00	38.112	58.182	72.706	10.52	4.48	6.73
02 Jul 2011 06:51:00	22.952	78.403	39.884	15.51	2.50	8.55
02 Jul 2011 06:51:00	21.235	63.755	34.451	13.24	2.39	7.79

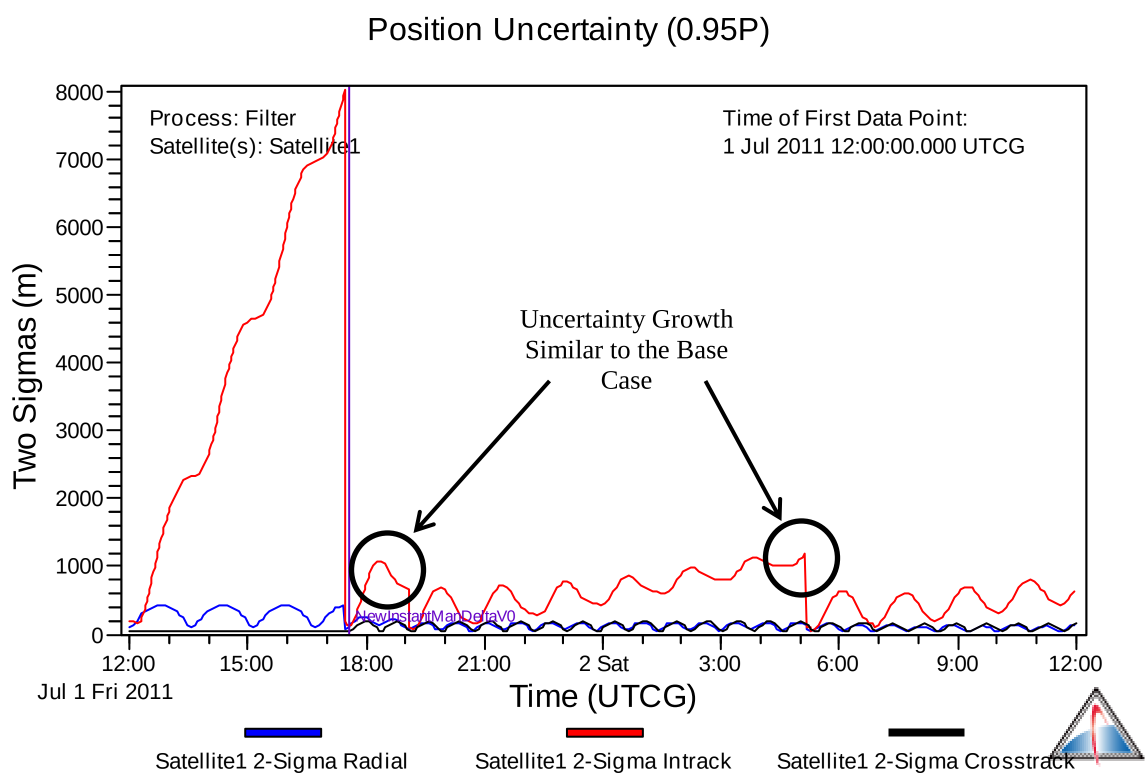

Figure 20 Crosstrack Maneuver, 10 m/s, *i* = 45° (Case 1i) Position Uncertainties

The measurement residuals for the 10 m/s intrack maneuver (Case 1h) are larger than the residuals for the previous intrack maneuvers for the second pass (Figure 21).

The initial range residual is at 678 m versus about 47 m for the 1 m/s maneuver and 325 m for the 5 m/s maneuver. By the end of the pass, however, the range residual is practically the same as the 1 m/s and 5 m/s range residuals. This means the model is far from the truth at the beginning of the pass, which is expected because of the maneuver, but it recovers quickly to similar values for the previous passes.

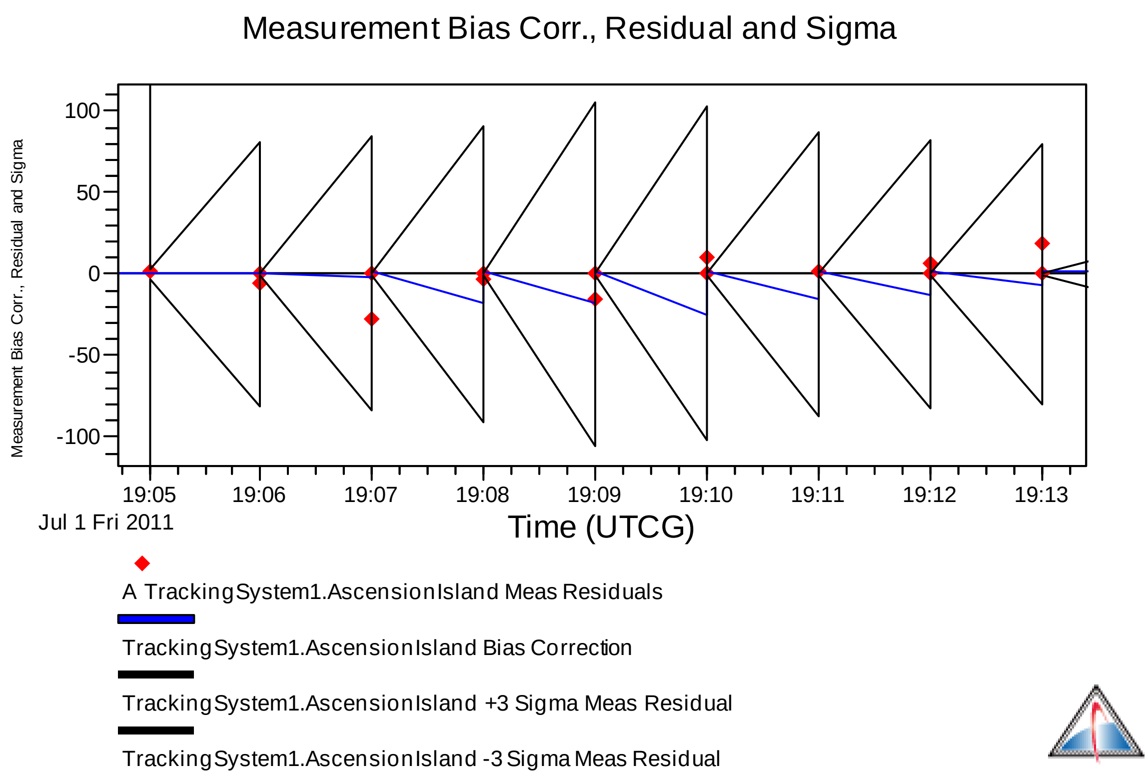

Figure 21 Intrack Maneuver, 10 m/s, *i* = 45° (Case 1h) Measurement Residuals, 2nd Pass

4.3.2 Cases 1j-1r, Maneuver at 19:20

Cases 1j-1r perform the maneuver immediately after the second pass, at 19:20. This creates a long drift time until the next pass at 05:10, approximately 10 hours. The long drift time may affect the ability of the filter to converge, since there is such a long time after the maneuver before any observations are made. The maneuver at 19:20 shifts the timing slightly for the last two passes. The pass at 5:10 is approximately 26 minutes

from T=0 at 04:44. This places it in a good position to detect uncertainties from a crosstrack maneuver. The pass at 06:51 is approximately 33 minutes from T=0 at 6:18. This is not the best position to detect the errors from any maneuver because it is at about 1/3T, but should be able to detect some error from any maneuver.

Cases 1j-1l use a 1 m/s maneuver at 19:20. Since this is a small maneuver, huge uncertainties are not expected. After comparing with Cases 1a-1c, it appears the longer drift time does not significantly affect the filter convergence. In many instances, the solution is actually slightly better with the longer drift time. This may be because the filter has two passes with no maneuvers, which allows it to converge on a solution faster. Therefore, it has a better solution, even with the maneuver directly after the second pass, which it can then update with the observations on the next two passes. The maneuver is also very small, so the satellite is not very far from where the filter expects it to be. The change in the time of the maneuver, which changes where the observations are taking place in the satellite's orbit (½T vs. ¼T) does not appear to have an effect. Table 16-

Table 18 show the position and velocity percentages for comparison to the Base Case and Cases 1a-1c.

Table 16 Radial Maneuver, 1 m/s, *i* = 45° (Case 1j) Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.77	63.43	0.16	57.69	8.91	0.08
Pass 3	36.99	91.11	0.46	88.34	30.92	0.00
Pass 4	3.72	17.09	4.42	15.04	1.98	0.04

Table 17 Intrack Maneuver, 1 m/s, *i* = 45° (Case 1k) Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.77	63.43	0.16	57.69	8.91	0.08
Pass 3	24.54	95.16	0.34	93.01	15.49	0.15
Pass 4	4.55	11.79	5.40	9.30	2.97	0.04

Table 18 Crosstrack Maneuver, 1 m/s, *i* = 45° (Case 1l) Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.77	63.43	0.16	57.69	8.91	0.08
Pass 3	37.73	91.09	0.40	88.30	31.54	0.00
Pass 4	3.76	16.83	4.91	14.78	2.00	0.10

Cases 1m-1o have a 5 m/s maneuver at 19:20. Again, the longer drift time does not significantly affect the filter. In several instances the cases with the longer drift time have better solutions for the fourth pass, mostly improving on the intrack position, radial velocity, and semi-major axis. The larger crosstrack maneuver (Case 1o) does create larger crosstrack uncertainty, shown in Figure 22. Since the third pass is in an ideal position to detect crosstrack error, and the maneuver is larger, this is expected. The final magnitudes closely matched the previous cases.

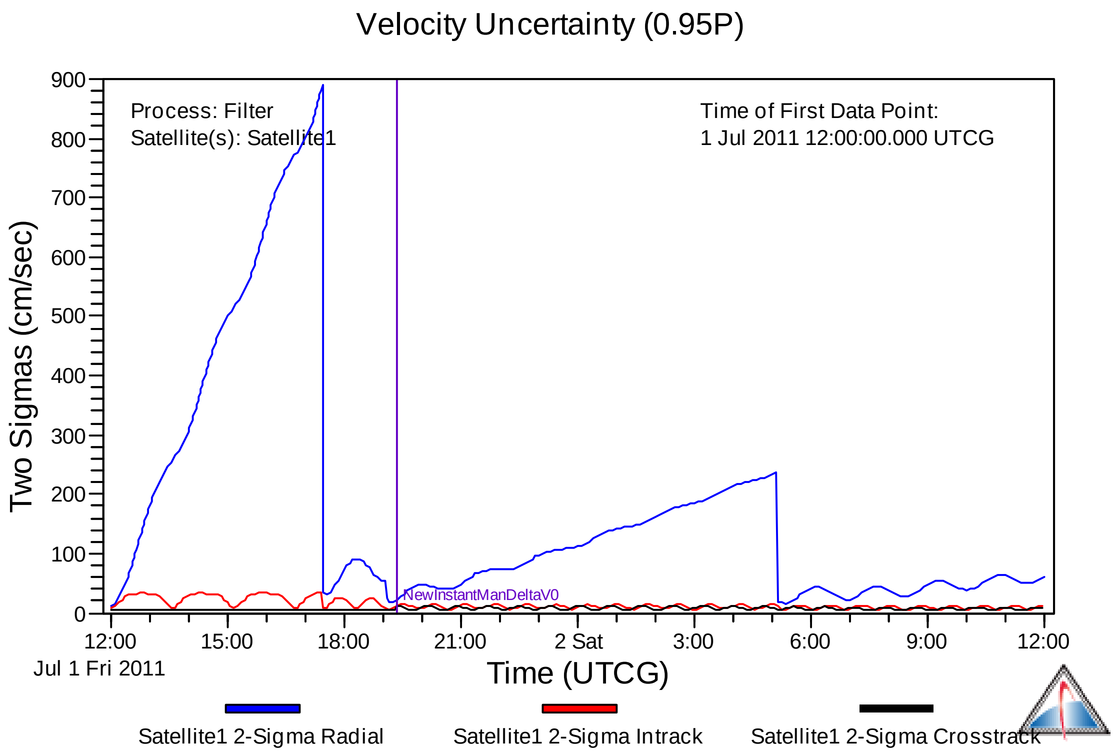

Figure 22 Crosstrack Maneuver, 5 m/s, *i* = 45° (Case 1o) Velocity Uncertainties

Cases 1p-1r have a 10 m/s maneuver at 19:20. Comparing the radial maneuver (Case 1p) to its sister case, the 10 m/s radial maneuver at 17:35 (Case 1g), Case 1p has a better intrack position and radial velocity solution. Case 1p has a better semi-major axis and eccentricity solution, but the magnitudes are so tiny the differences are trivial. Case 1g has a better radial and crosstrack position solution, but considering the maneuver is large and radial with a long drift time, and the satellite's orbit position at the time of passes three and four, greater uncertainty is expected. Considering the differences are on the order of a few meters or a few cm/s, the long drift time does not have a large effect on the filter results.

Comparing the intrack maneuver (Case 1q) to its sister case, the 10 m/s intrack maneuver at 17:35 (Case 1h), looking at just the percentages, the maneuver at 19:20 beat

out the maneuver at 17:35 because everything is zero (highlighted, Table 19). However one must remember the percentages compare how well the uncertainty at the time of the measurement and the uncertainty after the measurement update match. With the maneuver at 19:20 those numbers match perfectly. Referencing Wright (page 31), this means the state estimate structure contains unobservable parameters, so the filter is unable to perform the measurement update. However, comparing the magnitudes (highlights, Table 20) at the third pass, the intrack uncertainty for the maneuver at 19:20 went from 10,400 m to 60 m. The radial velocity went from 1170 cm/s to 10 cm/s. The filter still converges as well as the maneuver at 17:35 by the fourth pass, reinforcing the small effect of the long drift time. Case 1q is the only case where a parameter is unobservable; perhaps this is due to the elliptic orbit created after the 10 m/s maneuver.

Table 19 Intrack Maneuver, 10 m/s, *i* = 45° (Case 1q) Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.77	63.43	0.16	57.69	8.91	0.08
Pass 3	73.20	99.42	4.82	99.14	60.18	13.37
Pass 4	0.00	0.00	0.00	0.00	0.00	0.00

Table 20 Intrack Maneuver, 10 m/s, *i* = 45° (Case 1q) Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	**Radial**	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.124	140.955	19.665	27.11	3.50	2.14
01 Jul 2011 19:05:00	28.744	51.546	19.633	11.47	3.19	2.13
02 Jul 2011 05:13:00	158.558	10,391.851	27.707	1,166.83	12.25	2.56
02 Jul 2011 05:13:00	42.494	59.906	26.372	10.02	4.88	2.22
02 Jul 2011 06:54:00	23.480	67.705	24.835	12.94	2.60	2.40
02 Jul 2011 06:54:00	23.480	67.705	24.835	12.94	2.60	2.40

Comparing the 10 m/s crosstrack maneuver at 19:20 (Case 1r) to its sister case, the 10 m/s maneuver at 17:35 (Case 1i), percentage wise the maneuver at 19:20 is worse for the crosstrack position (highlight, Table 21). The maneuver at 19:20 does better than the maneuver at 17:35 with radial and intrack position. However the maneuver at 19:20 is significantly better with the crosstrack velocity magnitude, with a difference of 4.4 cm/s, possibly because the third pass is in a better position to detect the crosstrack maneuver uncertainty (Figure 23). The 10 m/s maneuver at 19:20 also creates a larger growth in the radial velocity uncertainty between the second and third passes.

Table 21 Crosstrack Maneuver, 10 m/s, *i* = 45° (Case 1r) Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.77	63.43	0.16	57.69	8.91	0.08
Pass 3	27.44	96.74	0.04	95.35	14.28	0.53
Pass 4	9.48	10.17	26.24	5.42	7.52	15.42

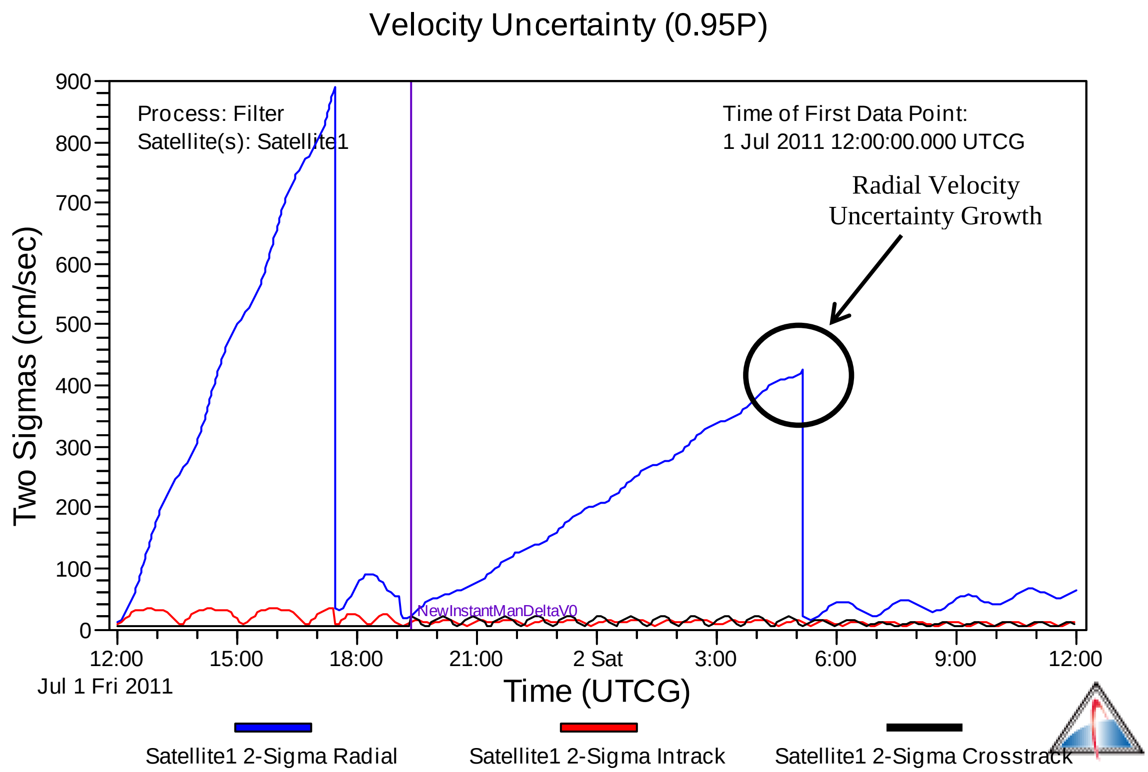

Figure 23 Crosstrack Maneuver, 10 m/s, *i* = 45° (Case 1r) Velocity Uncertainties

4.3.3 Cases 1s-1aa, Maneuver at 05:00

Cases 1s-1aa perform the maneuver immediately before the third pass, at 05:00. Because the maneuver is performed only 10 minutes before the pass, uncertainties are expected to increase with the magnitude of the maneuver. The fourth pass is approximately 17 minutes after T=0 for the maneuver. The filter should be able to detect most of the error from a crosstrack maneuver, but not from radial or intrack maneuvers. Filter performance is expected to suffer. Cases 1s-1u use a 1 m/s maneuver, Cases 1v-1x use a 5 m/s maneuver, and Cases 1y-1aa use a 10 m/s maneuver.

Comparing the 05:00 1 m/s intrack maneuver (Case 1s) to the maneuver at 19:20 (Case 1j), the maneuver at 05:00 has larger uncertainty, but not significantly more. The intrack uncertainty for the maneuver at 19:20 is 17% versus 19% for the maneuver at

05:00. Comparing the maneuver at 05:00 to the 1 m/s intrack maneuver at 17:35 (Case 1a), the maneuver at 05:00 has larger uncertainty, but not significantly more. For example, the semi-major axis for the maneuver at 17:35 is 14% and for the maneuver at 05:00 it is 15%, supporting the conclusion a small maneuver does not affect filter performance, regardless of the time of the maneuver.

Comparing the intrack maneuver at 05:00 (Case 1t) to the maneuver at 19:20 (Case 1k), the maneuver at 05:00 has significantly greater uncertainty than the maneuver at 19:20. The maneuver at 19:20 comes within 12% for intrack position, with the final magnitude at 61 m. For the maneuver at 05:00, the uncertainty is 51%, with the final magnitude at 91 m (highlights, Table 22). The radial velocity uncertainty is also large, 49% versus 9%, though the final magnitude for the maneuver at 05:00, 12.25 cm/s, is close to the final magnitude for the maneuver at 19:20, 11.3 cm/s. The semi-major axis difference is large, though the final magnitude is not far off from the maneuver at 19:20, at 9.85 m versus 5.94 m. Comparing the maneuver at 05:00 to the intrack maneuver at 17:35 (Case 1b) is a similar story as Case 1t to Case 1k. The large intrack uncertainty for the maneuver at 05:00 is surprising, considering the maneuver magnitude is very small (Figure 24). However, given the satellite's position relative to the time of the maneuver and the pass, and since the intrack position is the most difficult to track, this should have been expected. Performing an intrack maneuver directly before a pass may be the best way to stump the filter, especially after it has used data from previous passes to generate an orbit estimate.

Table 22 Intrack Maneuver, 1 m/s, *i* = 45° (Case 1t) Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	**Radial**	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.124	140.955	19.665	27.11	3.50	2.14
01 Jul 2011 19:05:00	28.744	51.546	19.633	11.47	3.19	2.13
02 Jul 2011 05:10:00	49.297	601.499	21.256	63.86	5.25	2.24
02 Jul 2011 05:10:00	29.838	55.732	21.153	7.72	3.49	2.24
02 Jul 2011 06:51:00	23.053	185.207	20.710	23.81	2.37	2.31
02 Jul 2011 06:51:00	20.765	91.068	20.347	12.25	2.36	2.31

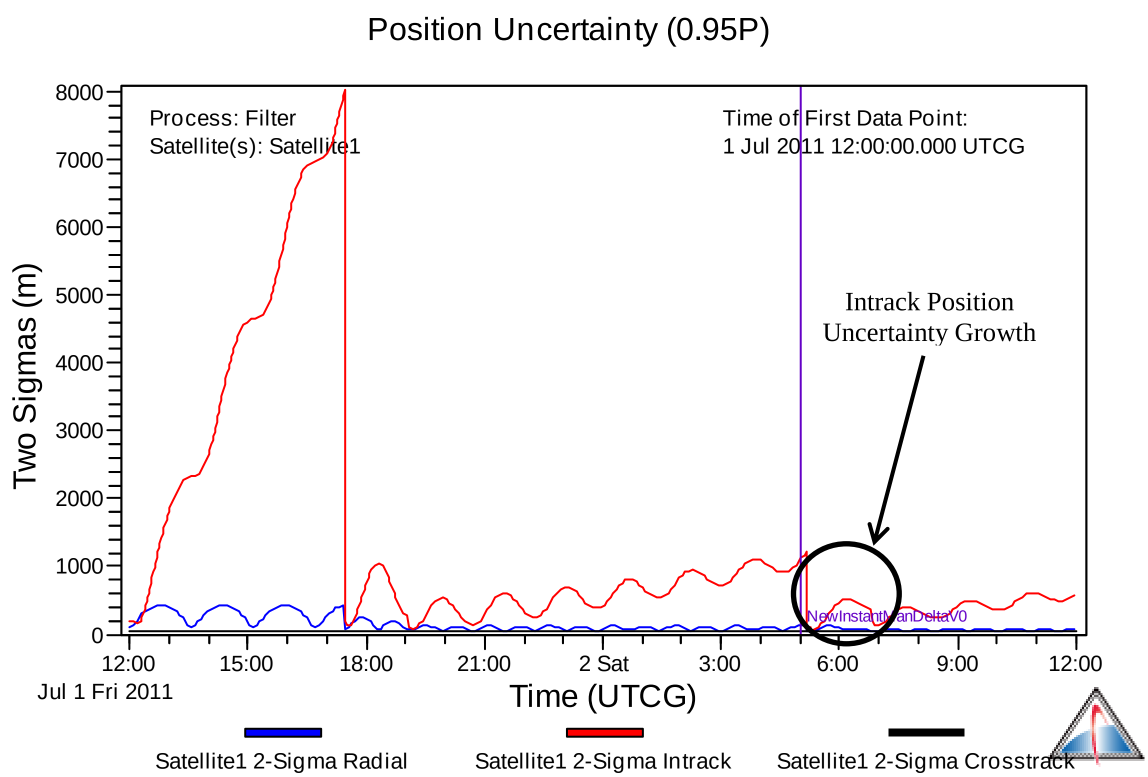

Figure 24 Intrack Maneuver, 1 m/s, *i* = 45° (Case 1t) Position Uncertainties

Comparing the 1 m/s crosstrack maneuver at 05:00 (Case 1u) to the 1 m/s crosstrack maneuver at 19:20 (Case 1l), the crosstrack maneuver at 05:00 does create

larger uncertainty, but not significantly. The intrack position uncertainty is 19% for the maneuver at 05:00 versus 17% for the maneuver at 19:20. Comparing the maneuver at 05:00 to the maneuver at 17:35 does not show anything hugely different. This is expected considering the small magnitude of the maneuver.

The 5 m/s radial maneuver at 05:00 for Case 1v does significantly increase the uncertainties for Case 1v compared to the 5 m/s radial maneuver at 19:20 (Case 1m), shown in Table 23. The intrack uncertainty for the maneuver at 05:00 is 45% and at 90 m, versus 17% and 59 m for the maneuver at 19:20. The radial velocity is also significant, for the maneuver at 05:00 it is 44% and 12 cm/s versus 13% and 11 cm/s for the maneuver at 19:20. The semi-major axis is also off by a few meters. The 5 m/s radial maneuver at 1735 (Case 1d) has slightly higher uncertainty than the maneuver at 19:20; otherwise the comparison to the maneuver at 05:00 is the same. As expected, the uncertainties increase with the increase in the maneuver magnitude.

Table 23 Radial Maneuver, 5 m/s, *i* = 45° (Case 1v) Pos/Vel Sigma Percentages

	Position Sigma Percentages			**Velocity Sigma Percentages**		
	Radial	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.77	63.43	0.16	57.69	8.91	0.08
Pass 3	30.53	90.56	0.46	87.18	25.68	0.00
Pass 4	6.67	45.47	2.37	44.07	1.02	0.01

The 5 m/s intrack maneuver at 05:00 for Case 1w significantly increases uncertainty for the intrack position and radial velocity (Table 24). The final magnitude for radial position does match between the maneuver at 05:00 and the 5 m/s intrack maneuver at 19:20 (Case 1n), though the intrack position is 101 m versus 60 m. The final radial velocity does match between the cases, but the percentage for the maneuver at

05:00 is significantly higher, at 85%, versus 9% for the maneuver at 19:20. The semi-major axis uncertainty is at 11 m for the maneuver at 05:00 compared to 6 m for the maneuver at 19:20. The 5 m/s intrack maneuver at 17:35 (Case 1e) has slightly higher uncertainty than the maneuver at 19:20; otherwise the comparison to the maneuver at 05:00 is the same. The significant increase in uncertainty is expected due to the increase in the magnitude of the maneuver; it also follows the increase in uncertainty for the intrack maneuver seen in the 1 m/s intrack maneuver at 05:00 (Case 1t).

Table 24 Intrack Maneuver, 5 m/s, *i* = 45° (Case 1w) Pos/Vel Sigma Percentages

	Position Sigma Percentages			**Velocity Sigma Percentages**		
	Radial	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.77	63.43	0.16	57.69	8.91	0.08
Pass 3	31.89	90.62	0.46	85.57	25.54	0.00
Pass 4	46.24	86.18	0.74	85.39	1.07	0.03

The 5 m/s crosstrack maneuver at 05:00 in Case 1x increases the intrack position uncertainty more than anything else (Table 25). The intrack uncertainty for the maneuver at 05:00 is at 41%, with a final magnitude of 97 m; versus 14% and 60 m for the 5 m/s crosstrack maneuver at 19:20 (Case 1o). The maneuver at 05:00 crosstrack uncertainty is at 7%, with a final magnitude of 39 m, versus 14% and 36 m for the maneuver at 19:20. Compared to the 5 m/s crosstrack maneuver at 17:35 (Case 1f), the maneuver at 17:35 intrack position uncertainty is at 19% with a magnitude of 61 m, and the crosstrack position uncertainty is at 7.5% with a magnitude of 25 m. Again, the increase in the maneuver magnitude increases the uncertainty, though the filter seems to detect more of the intrack error than the crosstrack error.

Table 25 Crosstrack Maneuver, 5 m/s, *i* = 45° (Case 1x) Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.77	63.43	0.16	57.69	8.91	0.08
Pass 3	39.22	90.68	0.17	87.88	33.17	0.01
Pass 4	9.99	41.36	7.07	38.99	1.29	2.00

Given the above results for the 5 m/s maneuvers at 05:00 (Cases 1v-1x), maneuvering directly before the third pass significantly increases uncertainties in various areas; because of the limited number of observations after the maneuver, this is expected.

The 10 m/s radial maneuver at 05:00 for Case 1y significantly increases the intrack position uncertainty and radial velocity uncertainty (Table 26). However, the final magnitude of the radial velocity does match the 10 m/s maneuver at 19:20 (Case 1p). The maneuver at 05:00 intrack position uncertainty is at 106 m versus 60 m for the maneuver at 19:20. The 10 m/s radial maneuver at 17:35 (Case 1g) has slightly worse intrack position uncertainty than the maneuver at 19:20; otherwise the comparison to the maneuver at 05:00 is similar. The increase in uncertainty for the maneuver at 05:00 is expected due to the increase in the maneuver magnitude.

Table 26 Radial Maneuver, 10 m/s, *i* = 45° (Case 1y) Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.77	63.43	0.16	57.69	8.91	0.08
Pass 3	20.09	90.06	0.41	85.04	16.90	0.00
Pass 4	7.25	65.37	1.31	64.92	0.00	0.00

The 10 m/s intrack maneuver at 05:00 for Case 1z creates a large increase in the intrack position and radial velocity uncertainty. The maneuver at 05:00 intrack position is at 135 m versus 68 m for the maneuver at 19:20 (Case 1q), and the radial velocity is at

17 cm/s for the maneuver at 05:00 versus 13 cm/s for the maneuver at 19:20. The maneuver at 05:00 semi-major axis is at 15 m versus 6 m for the maneuver at 19:20. Comparing the maneuver at 05:00 to the 10 m/s intrack maneuver at 19:20 (Case 1h), the maneuver at 19:20 intrack position uncertainty is a little better at 60 m. The increase in uncertainty for the 10 m/s maneuver at 05:00 is similar to the 5 m/s maneuver at 05:00, but even worse, shown in Figure 25.

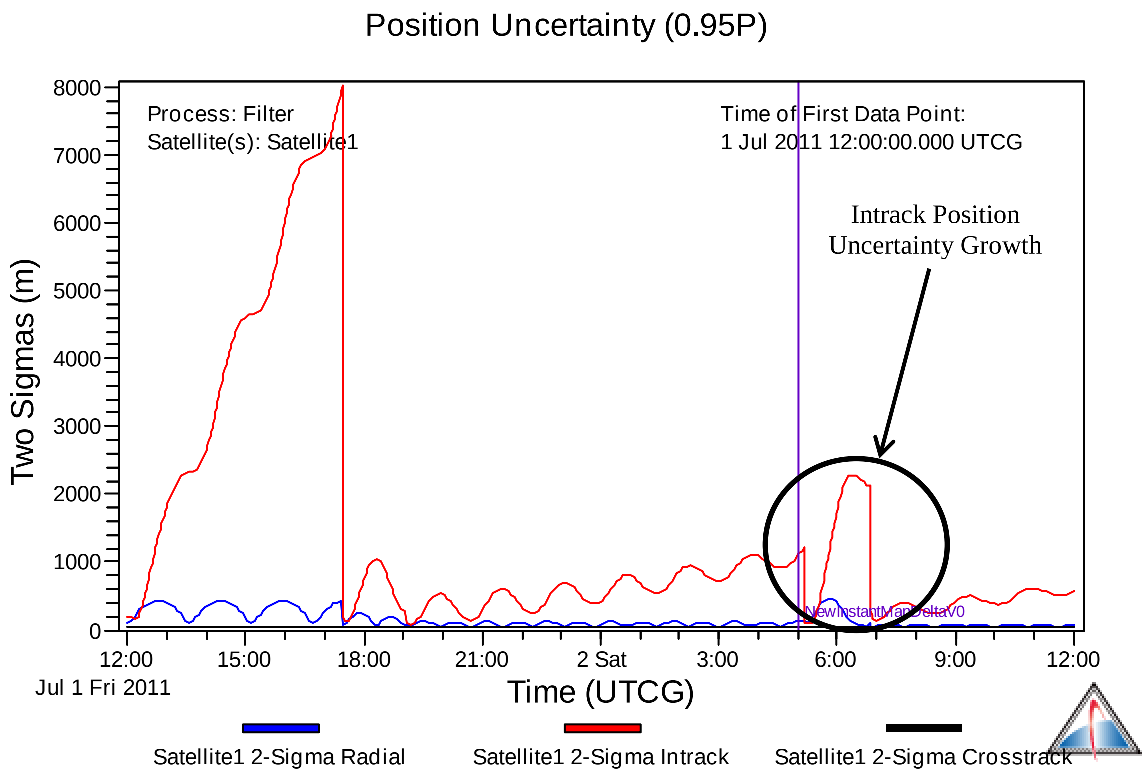

Figure 25 Intrack Maneuver, 10 m/s, *i* = 45° (Case 1z) Position Uncertainties

The 10 m/s crosstrack maneuver at 05:00 for Case 1aa also creates large uncertainties (Table 27). The maneuver at 05:00 intrack position is at 57% and 130 m, with the maneuver at 19:20 (Case 1r) at 10% and 62 m. The maneuver at 05:00 crosstrack position is at 10% and 61 m, with the maneuver at 19:20 at 26% and 49 m. The maneuver at 05:00 radial velocity is at 56% and 17 cm/s, with the maneuver at 19:20

at 5% and 12 cm/s (Figure 26). The maneuver at 05:00 crosstrack velocity is at 6% and 4 cm/s, with the maneuver at 19:20 at 15% and 3 cm/s. The 10 m/s crosstrack maneuver at 17:35 (Case 1i) has similar results to the maneuver at 19:20.

Table 27 Crosstrack Maneuver, 10 m/s, *i* = 45° (Case 1aa) Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.77	63.43	0.16	57.69	8.91	0.08
Pass 3	37.33	90.51	0.10	87.46	31.28	0.03
Pass 4	21.48	57.47	9.72	55.87	1.15	5.89

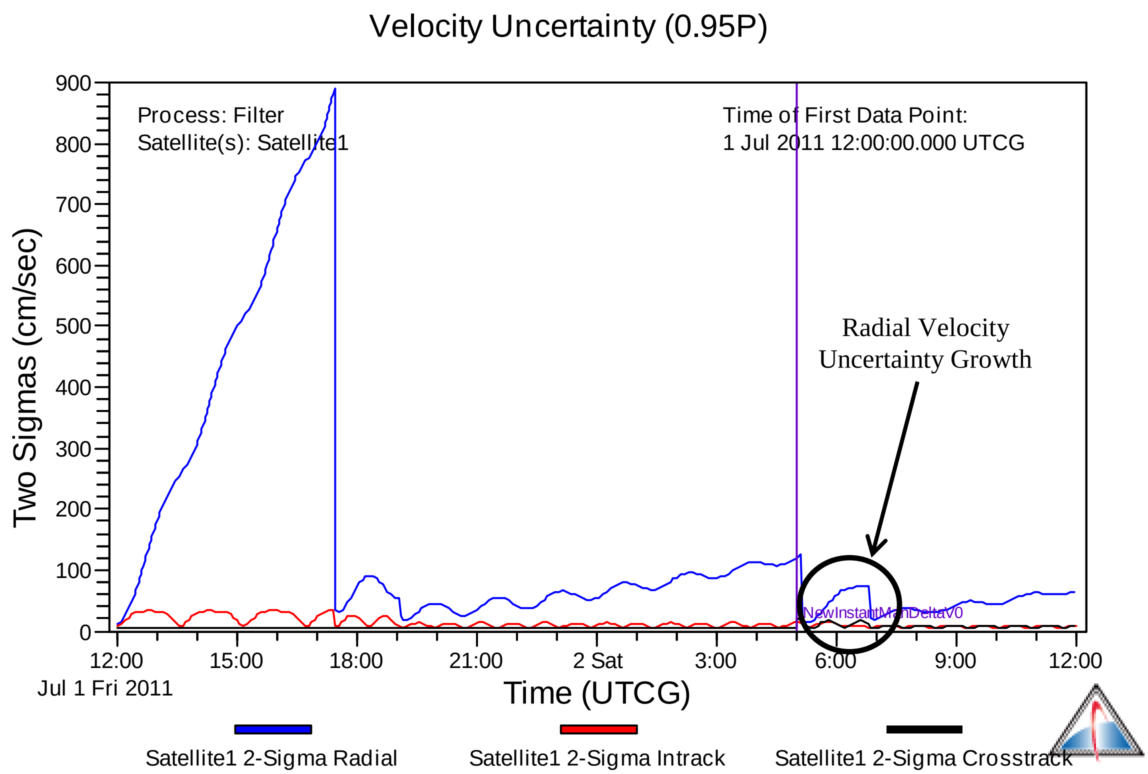

Figure 26 Crosstrack Maneuver, 10 m/s, *i* = 45° (Case 1aa) Velocity Uncertainties

From the above results for the 10 m/s maneuvers at 05:00 (Cases 1y-1aa), the filter could not handle a large maneuver directly before a pass. The large increase for intrack uncertainty may be partially due to the fact the filter has mostly converged on an

orbit solution from the first two passes, and then basically has that solution thrown out the window when the satellite is not where the filter expected it to be on the third pass.

4.4 Case 2 Variants

All Case 2 variants use a 90° inclination, and the 1 m/s maneuver is omitted because the results from the majority of Case 1 variants show no significant impact to the filter. The number of measurements per pass for Case 2 is shown in Table 28.

Table 28 Case 2 (*i* = 90°) Pass Summary

	Start Time	Stop Time	Number of Measurements
Pass 1	01 Jul 2011 17:30	01 Jul 2011 17:36	21
Pass 2	01 Jul 2011 19:04	01 Jul 2011 19:10	21
Pass 3	02 Jul 2011 05:16	02 Jul 2011 05:20	15
Pass 4	02 Jul 2011 06:49	02 Jul 2011 06:56	24

4.4.1 Cases 2a-2f, Maneuver at 17:40

For Case 2a, a 5 m/s radial maneuver, the intrack position uncertainty is significant until the fourth pass, which brings it down to 60 m, shown in Figure 27. The radial velocity also has significant uncertainty until the fourth pass, which brings it down to 11.5 cm/s. The intrack and crosstrack maneuvers (Case 2b and Case 2c) have similar results. As a set, these are similar to the results for the 5 m/s maneuvers at 17:35 for Case 1 (Cases 1d-1f), where the inclination is 45°. This demonstrates there is no significant variation in uncertainty based on the orbit plane change (from 45° to 90°).

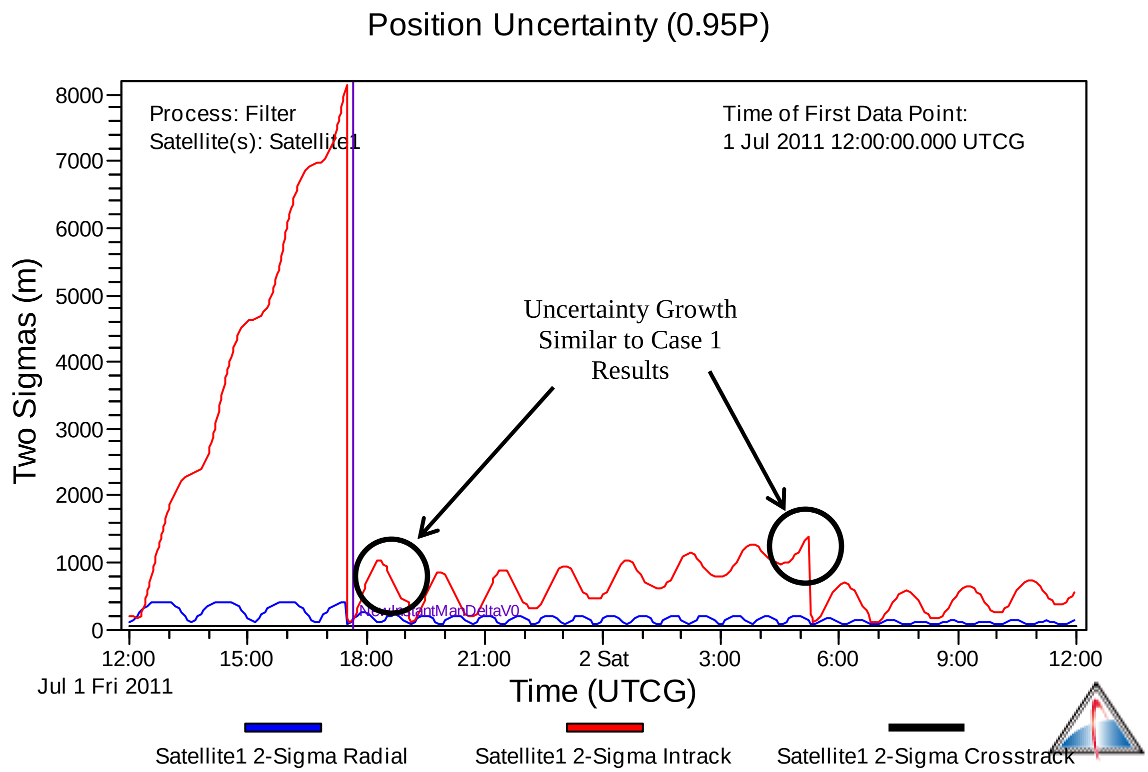

Figure 27 Radial Maneuver, 5 m/s, *i* = 90° (Case 2a) Position Uncertainties

Cases 2d-2f use a 10 m/s maneuver at 17:40. Comparing the 10 m/s radial maneuver (Case 2d) to the 5 m/s radial maneuver (Case 2a), the radial position uncertainty remains significant at 54 m, even though the percentage is only 3%. The intrack position uncertainty, radial velocity, and intrack velocity uncertainty increase slightly. The classical element uncertainties remain essentially the same between cases. Comparing the 10 m/s intrack maneuver (Case 2e) to the 5 m/s intrack maneuver (Case 2b), there is essentially no difference between the two. The uncertainty percentages and magnitudes are not significantly different. Comparing the 10 m/s crosstrack maneuver (Case 2f) to the 5 m/s crosstrack maneuver (Case 2c), the 10 m/s maneuver shows a slight increase in all of the position and velocity sigmas, however all converge to about the same point as the 5 m/s maneuver by the fourth pass. The 10 m/s crosstrack maneuver

does show a 1.6 cm/s increase in the crosstrack velocity uncertainty compared to the 10 m/s radial and intrack maneuvers (Case 2d and Case 2e). This is similar to the increase in the crosstrack velocity uncertainty from the 10 m/s crosstrack maneuver at 17:35 from Case 1 (Case 1i), though not as large. Based on these results, the 10 m/s maneuver does not significantly increase the uncertainties, even though the maneuver magnitude increased.

4.4.2 Cases 2g-2l, Maneuver at 19:20

Cases 2g-2i use a 5 m/s maneuver at 19:20. Compared to the 5 m/s radial maneuver at 17:40 (Case 2a), the 5 m/s radial maneuver at 19:20 (Case 2g) has a slightly worse radial position uncertainty at 46 m versus 38 m for the maneuver at 17:40. Otherwise the uncertainties are very similar between the cases (Table 29). The long drift time does not appear to affect the solution.

Table 29 Radial Maneuver, 5 m/s, *i* = 90° (Case 2g) Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	**Radial**	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
01 Jul 2011 17:30:00	207.908	4,066.797	20.858	450.60	16.43	2.10
01 Jul 2011 17:30:00	32.205	84.180	20.858	14.92	3.39	2.10
01 Jul 2011 19:04:00	28.960	118.261	19.967	23.87	3.15	2.12
01 Jul 2011 19:04:00	28.422	61.690	19.581	13.31	3.15	2.12
02 Jul 2011 05:16:00	58.558	1,138.428	22.307	124.26	6.09	2.24
02 Jul 2011 05:16:00	46.639	144.365	22.258	17.76	5.28	2.24
02 Jul 2011 06:49:00	46.192	103.446	21.365	16.62	5.24	2.23
02 Jul 2011 06:49:00	45.730	60.786	21.161	10.83	5.14	2.22

The 5 m/s intrack maneuver at 19:20 (Case 2h) has virtually the same results as the 10 m/s intrack maneuver at 17:40 and the 5 m/s intrack maneuver at 17:40, which shows the long drift time and change in maneuver magnitude have minimal effect. The 5 m/s crosstrack maneuver at 19:20 (Case 2i) has virtually identical results as the 5 m/s crosstrack maneuver at 17:40; further evidence the long drift time does not affect the filter convergence.

Cases 2j-2l use a 10 m/s maneuver at 19:20. Compared to the 10 m/s radial maneuver at 17:40 (Case 2d), the radial maneuver at 19:20 (Case 2j) has significantly greater uncertainties for the radial position, with the maneuver at 19:20 at 70 m and the maneuver at 17:40 at 54 m (Figure 28). The intrack position uncertainty also increase, with the maneuver at 19:20 at 72 m and the maneuver at 17:40 at 67 m. The maneuver at 19:20 has a slightly smaller radial velocity uncertainty, and a slightly higher intrack velocity uncertainty. With the maneuver at 19:20, it appears combining drift time with the larger maneuver magnitude may be a factor for the increase in radial position uncertainty.

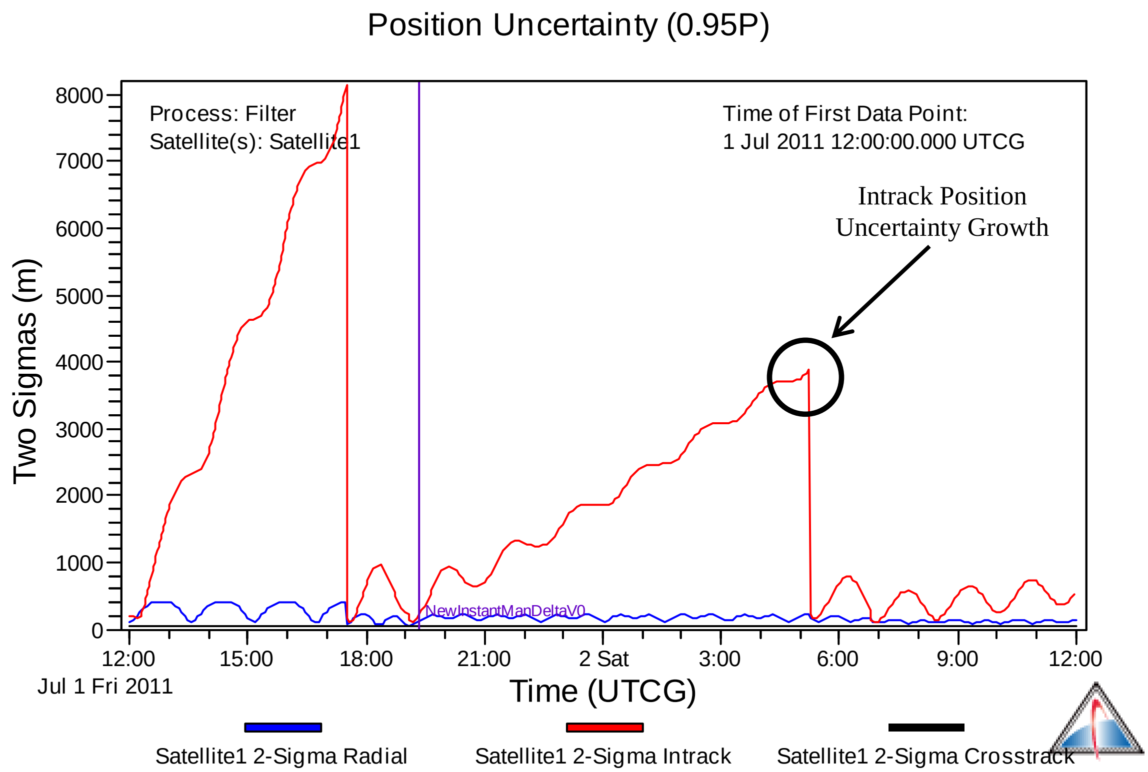

Figure 28 Radial Maneuver, 10 m/s, i = 90° (Case 2j) Position Uncertainties

The 10 m/s intrack maneuver at 19:20 (Case 2k) has slightly higher uncertainty compared to the 10 m/s intrack maneuver at 17:40 (Case 2e), but nothing significant. There is no noticeable effect from drift time. The 10 m/s crosstrack maneuver at 19:20 (Case 2l) has slightly worse uncertainty for the radial and crosstrack position compared to the 10 m/s crosstrack maneuver at 17:40 (Case 2f). Again, it is nothing significant, so it appears only the large radial maneuver (Case 2j) combining with the long drift time has a significant effect on the filter.

4.4.3 Cases 2m-2r, Maneuver at 05:00

Cases 2m-2r perform the maneuver on 2 July 2011 at 05:00, directly preceding the third pass. Greater uncertainty is expected, similar to the results from the Case 1 variants.

The 5 m/s radial maneuver at 05:00 (Case 2m) has a slightly better radial position uncertainty, but is worse on intrack position uncertainty compared to the 5 m/s radial maneuver at 19:20 (Case 2g). The crosstrack position uncertainty is virtually the same. Compared to the 5 m/s radial maneuver at 17:40 (Case 2a), the maneuver at 05:00 has a better radial velocity, at 8.84 cm/s versus 11.48 cm/s for the maneuver at 17:40 (Figure 29). The maneuver at 05:00 has slightly worse radial and intrack position, and virtually the same crosstrack position uncertainty. Intrack and crosstrack velocity are the same.

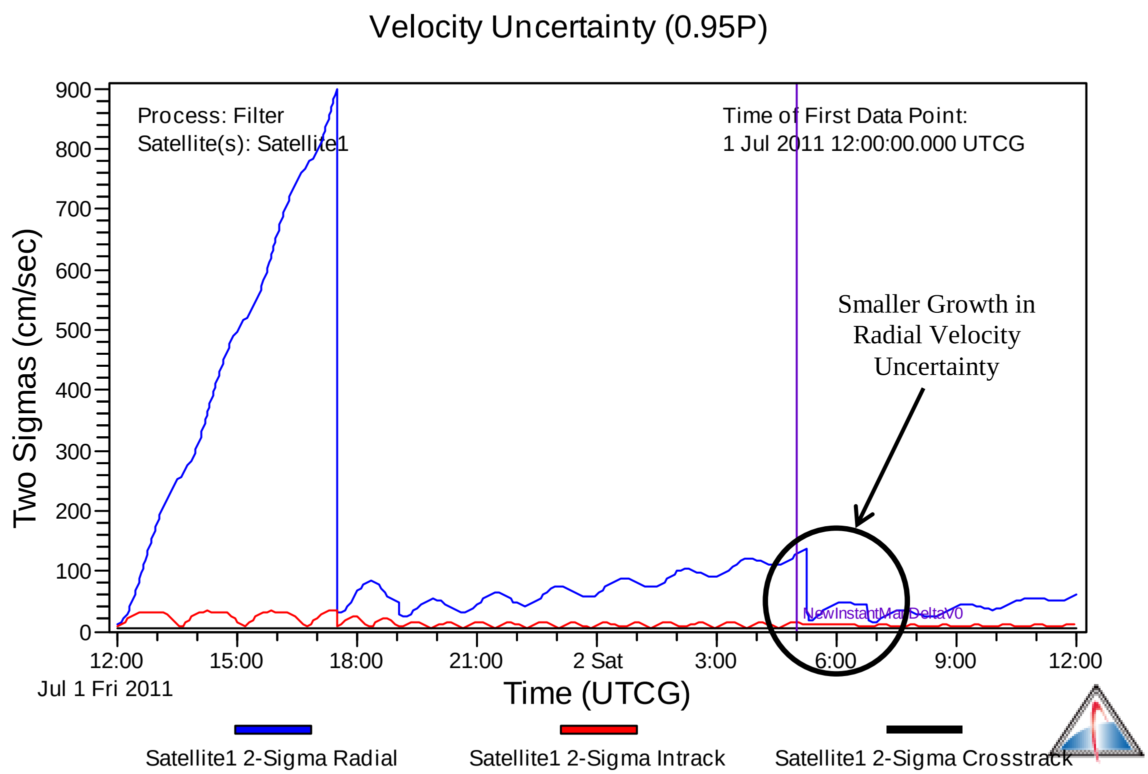

Figure 29 Radial Maneuver, 5 m/s, *i* = 90° (Case 2m) Velocity Uncertainties

The 5 m/s intrack maneuver at 05:00 (Case 2n) has slightly better radial position, but worse intrack position by about 8 m than the 5 m/s intrack maneuver at 19:20 (Case 2h). The crosstrack position is virtually the same. The maneuver at 05:00 has a better

radial velocity at 8.85 cm/s versus 11.03 cm/s for the maneuver at 19:20. The 5 m/s intrack maneuver at 17:40 (Case 2b) is virtually the same as the maneuver at 19:20.

The 5 m/s crosstrack maneuver at 05:00 (Case 2o) has the best radial position, and slightly worse intrack position (difference of 5 m), and the best crosstrack position compared to the 5 m/s crosstrack maneuver at 19:20 (Case 2i) and the 5 m/s crosstrack maneuver at 17:40 (Case 2c). The maneuver at 05:00 has the best radial velocity at 8.9 cm/s versus 10.5 cm/s for the maneuver at 19:20 and 11 cm/s for the maneuver at 17:40. The intrack and crosstrack velocity uncertainties are virtually the same across the cases.

Cases 2p-2r performed a 10 m/s maneuver at 05:00. The radial maneuver, Case 2p, has a better radial position than the 10 m/s radial maneuver at 19:20 (Case 2j), but is worse than the 10 m/s radial maneuver at 17:40 (Case 2d). The intrack position for the maneuver at 05:00 is slightly better than the maneuver at 19:20, but again worse than the maneuver at 17:40, at 72 m versus 67 m. The crosstrack position is virtually the same among the three cases. The maneuver at 05:00 has the best radial velocity at 9 cm/s versus 13 cm/s for the other two. The intrack and crosstrack velocity uncertainties were virtually the same.

Comparing the 10 m/s intrack maneuver at 05:00 (Case 2q), to the 10 m/s intrack maneuver at 19:20 (Case 2k), and the 10 m/s intrack maneuver at 17:40 (Case 2e) the position uncertainties are virtually same across all three cases. The maneuver at 05:00 has the best radial velocity at 8.8 cm/s versus 11.1 and 11.9 cm/s for the maneuver at 19:20 and the maneuver at 17:40, respectively.

Comparing the 10 m/s crosstrack maneuver at 05:00 (Case 2r) to the 10 m/s maneuver at 19:20 (Case 2l), and the 10 m/s maneuver at 17:40 (Case 2f), the radial

position is virtually the same across cases. The maneuver at 05:00 has the worst intrack position, at 67 m versus 59 m for the other two. However the maneuver at 05:00 has the best crosstrack position, at 40 m versus 47 m and 44 m for the maneuver at 19:20 and the maneuver at 17:40, respectively. The maneuver at 05:00 has the best radial velocity at 9 cm/s versus 11.3 cm/s for the maneuver at 19:20 and 11.9 cm/s for the maneuver at 17:40.

Based on these results, it appears performing the maneuver at 05:00 actually slightly improved the filter performance, especially for the radial velocity solution, instead of generating significantly larger uncertainties. This may be due to the orbit geometry created with the inclination at 90°.

4.5 Case 3 Variants

For the Case 3 variants, the number of measurements is approximately halved from the Case 1 variants. The time interval option in the simulator is used to manually halve the times of each pass in order to reduce the number of measurements. Since this is based solely on time, and not orbit geometry, a few cases have significantly fewer measurements or none at all. For example, for Case 3e and Case 3k, the fourth pass is lost completely, with zero measurements. However, most cases have the number of measurements defined in Table 8. The 1 m/s maneuver is not included, since it does not significantly affect the filter results.

4.5.1 Cases 3a-3f, Maneuver at 17:35

Cases 3a-3c use a 5 m/s maneuver at 17:35. Compared to the Base Case, all of these cases have greater uncertainty. The radial maneuver (Case 3a) has slightly greater

uncertainty than the radial maneuver with all the observations (Case 1d). The final magnitudes still match fairly well, with Case 3a a few meters higher than Case 1d. The intrack maneuver, Case 3b, has significantly greater intrack position uncertainty than the corresponding Case 1 variant, Case 1e; Case 3b is at 74 m and Case 1e is at 63 m. The other magnitudes match fairly well. Case 3c, the crosstrack maneuver, closely matches Case 1f. Case 3c does have a few meters higher uncertainty for the radial and intrack position.

Cases 3d-3f use a 10 m/s maneuver at 17:35. Case 3d, the radial maneuver, has slightly higher uncertainty for the radial position, intrack position, radial velocity, and intrack velocity compared to the corresponding Case 1 variant, Case 1g. The crosstrack position uncertainty matches. Case 3e, the intrack maneuver, does not have a fourth pass, due to the constraints mentioned above. Case 3e has higher radial position uncertainty, 19 m more, than Case 1h (Figure 30). Case 3e has slightly smaller intrack position uncertainty, and slightly larger crosstrack position uncertainty. Case 3e has slightly smaller radial velocity uncertainty, but 2 cm/s larger intrack velocity uncertainty than Case 1h.

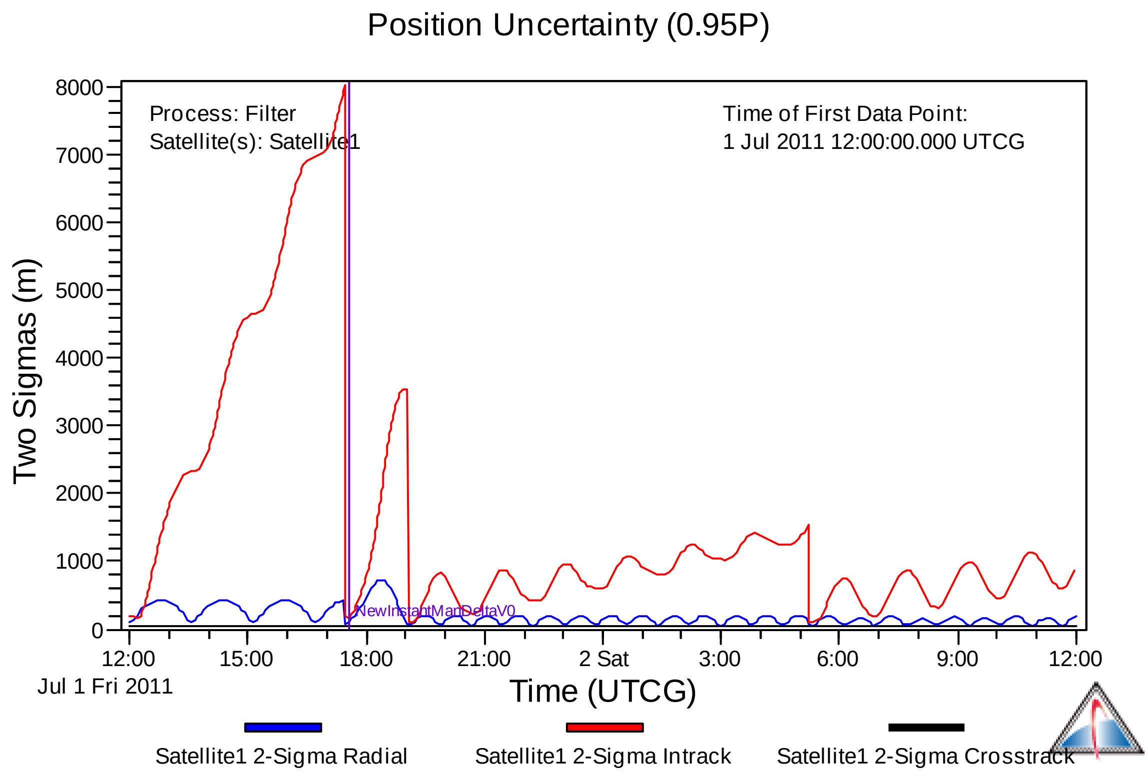

Figure 30 Intrack Maneuver, 10 m/s, *i* = 45° (Case 3e) Position Uncertainties

Case 3f, the crosstrack maneuver, has slightly larger radial position uncertainty but much larger intrack position uncertainty; while the crosstrack uncertainty matches the corresponding Case 1 variant, Case 1i. Case 3f has a slightly larger velocity uncertainty.

The reduced number of measurements has an impact, but not hundreds of meters of impact for these cases.

4.5.2 Cases 3g-3l, Maneuver at 19:20

Cases 3g-3i use a 5 m/s maneuver at 19:20. The radial maneuver, Case 3g, has greater radial and intrack position uncertainty than the corresponding Case 1 variant, Case 1m, a few meters in each direction. The crosstrack position matches. The radial velocity for Case 3g is higher by 2.5 cm/s, while the other velocity uncertainties are close. The intrack maneuver, Case 3h, has slightly larger radial position uncertainty by a

few meters compared to Case 1n. Case 3h has a larger intrack position uncertainty by 13 m. The crosstrack position matches between cases. Case 3h has a larger radial velocity uncertainty by about 3 cm/s. The crosstrack maneuver, Case 3i, has larger radial and intrack position uncertainties and larger velocity uncertainties compared to Case 1o. The crosstrack position uncertainty practically matches.

Cases 3j-3l use a 10 m/s maneuver at 19:20. The radial maneuver, Case 3j, has larger radial and intrack position uncertainties, a few meters, compared to Case 1p. The crosstrack position uncertainty practically matches. Case 3j has larger radial velocity uncertainty, about 2 cm/s, than Case 1p.

The intrack maneuver, Case 3k, does not have a fourth pass, similar to Case 3e (Figure 31). The radial position uncertainty is much larger, about 24 m, than the corresponding Case 1 variant, Case 1q. However Case 3k's intrack position uncertainty is better than Case 1q by about 7 m. Case 3k's crosstrack position uncertainty is slightly worse than Case 1q. Case 3k's radial velocity is slightly better, but the intrack velocity is off by about 3 cm/s compared to Case 1q. The crosstrack velocity matches with Case 1q. Since Case 1q in essence does not have a fourth pass, because one or more of the parameters is unobservable, the performance of the two cases is similar except for the radial position uncertainty.

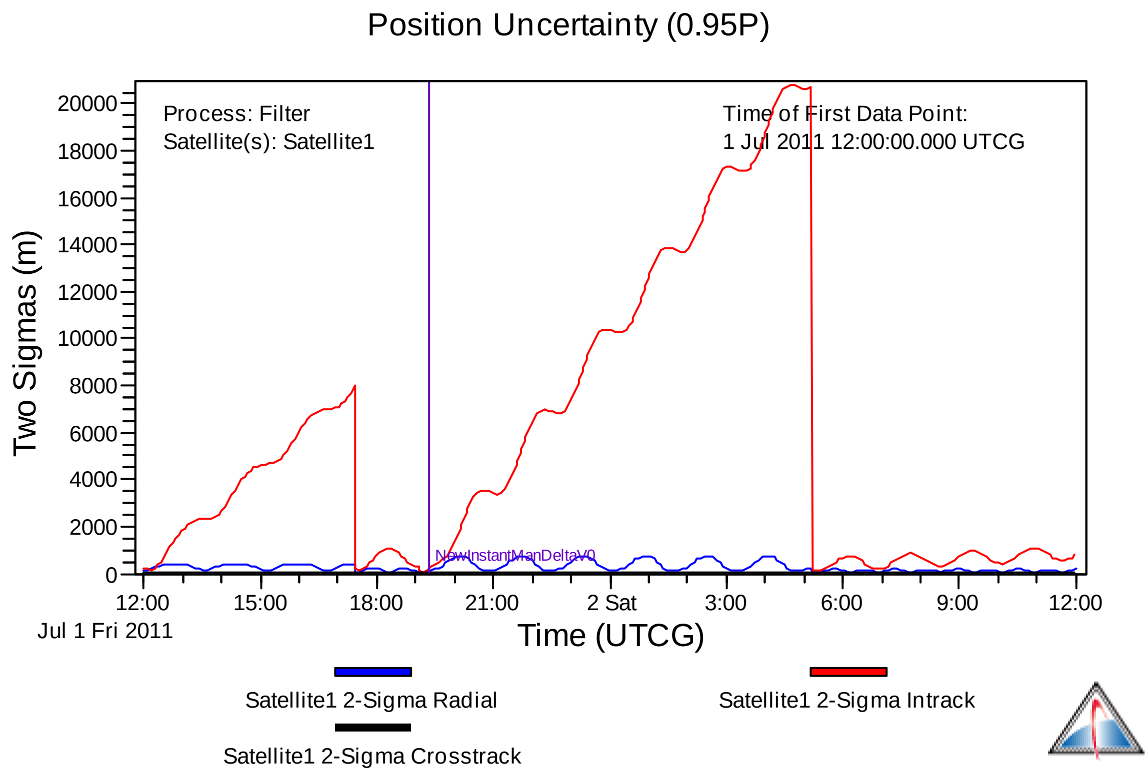

Figure 31 Intrack Maneuver, 10 m/s, *i* = 45° (Case 3k) Position Uncertainties

The crosstrack maneuver, Case 3l, has larger uncertainty for all position and velocity magnitudes compared to the corresponding Case 1 variant, Case 1r. The intrack position uncertainty is larger by 11 m, and the crosstrack position uncertainty is larger by 3 m. The radial velocity uncertainty is larger by 2.5 cm/s.

Even with the larger maneuver magnitude and reduced measurements, the filter still performs fairly well. It appears as long as there is at least one set of measurements (range, azimuth, and elevation) for each pass, the results were almost as good as having multiple sets of measurements.

4.5.3 Cases 3m-3r, Maneuver at 05:00

Cases 3m-3o use a 5 m/s maneuver at 05:00. All of these cases have slightly larger radial position uncertainty compared to their sister cases (Cases 1v-1x).

Otherwise, all other position and velocity uncertainties are very close. For this set of cases, the reduced number of measurements does not have a large effect.

Cases 3p-3r use a 10 m/s maneuver at 05:00. For these cases, there is an increase in the radial position uncertainty, and also some slight increases in the velocity uncertainties. However, there are no huge differences with their sister cases (Cases 1y-1aa), reinforcing the assertion that as long as there is at least one set of measurements for each pass, the results are almost as accurate as having multiple sets of measurements.

4.6 Summary

The results from each case are compared to determine which variables had an impact on the filter performance. Results from some cases are highlighted with graphs and tables to show the filter behavior, covariance values, and measurement residuals. The overall study conclusions are in Chapter 5.

V Conclusion

Performing a maneuver directly before a pass generates the most uncertainty in the filter. In particular, an intrack maneuver directly before a pass may be the best way to stump the filter, especially after it has used data from previous passes to generate an orbit estimate. Since the filter already has an orbit estimate, performing the maneuver at 05:00 basically nullifies the available orbit estimate and it takes time for the filter to recover and provide an updated orbit estimate. From the Case 1 variants, the Cases generating the most uncertainty are the cases with the maneuver at 05:00. For example, Case 1t, with a 1 m/s intrack maneuver, creates a 91 m intrack position uncertainty. Performing the maneuver at 17:35 or 19:20 does generate some uncertainties based on the maneuver direction, but none are as large as the uncertainties with the maneuver at 05:00. The case with the most uncertainty is Case 1z, with the 10 m/s intrack maneuver at 05:00. This creates a 135 m intrack position uncertainty. Therefore, drift time does not significantly affect filter convergence.

For Case 2, unlike Case 1, performing the maneuver at 05:00 does not create larger uncertainty, but changes where the uncertainty is evident. For example, for Cases 2n and 2q, with intrack maneuvers, the larger uncertainty appears in the intrack position, versus the radial velocity for the previous cases with an intrack maneuver. For Cases 2o and 2r, with a crosstrack maneuver, there is greater uncertainty in the intrack position instead of just the crosstrack position compared to previous cases. The intrack position uncertainty never gets as large as some of the instances in the Case 1 variants; the largest uncertainty is 72 m. Otherwise, all of the Case 2 variants consistently generate uncertainty depending on the maneuver. The radial maneuver always creates uncertainty

for the radial and intrack position, and the radial and/or intrack velocity. The intrack maneuver generates uncertainty in the radial velocity or the intrack position. The crosstrack maneuver generates uncertainty in the crosstrack position and in two cases the intrack position.

Fewer measurements do not have a significant effect for the Case 3 variants; as long as there is at least one measurement for each pass, the filter converges to relatively the same point as the Case 1 variants. However, the Case 3 variants do show uncertainties in more elements. For example, the Case 1 intrack maneuvers always have uncertainty in the radial velocity; for the Case 3 intrack maneuvers, there is also larger uncertainty in the intrack or radial position. For the last six variants in each case, with the maneuver at 05:00, the uncertainties practically match. For example, Case 1w has a 101 m intrack position uncertainty, and Case 3n has a 100 m intrack position uncertainty. Both also have uncertainty in the radial velocity. It would be the owner/operator's responsibility to determine a preferred uncertainty threshold, in order to determine how many measurements are needed for a particular case.

Overall, the performance of the optimal sequential filter is very good, especially when compared to the LS method. The measurement residuals provided for some of the Case 1 maneuvers show the model is close to truth, which indicate the filter is providing useful covariance values. The filter is able to predict the orbit of the satellite after a maneuver generally within the convergence criteria chosen. While the large maneuvers do create larger uncertainties, this could be mitigated with a few more observations. This should not be that difficult, considering these scenarios use only one ground station, while in actual tracking systems there are multiple ground stations available to provide

observations. Just a few minutes a couple times per day would provide enough measurements for the filter to generate an orbit solution with only a few meters of uncertainty, even if the satellite maneuvers.

For future research, additional orbit cases could be used to characterize the performance of the filter. Elliptical, sun synchronous, and retrograde orbits could be examined. Instead of using simulated data for the observations, real-world data could be used to improve the model, and further characterize the performance of the filter. Comparing station keeping maneuvers, which are generally small magnitude maneuvers, to orbit transfer maneuvers, would provide additional insight into the filter performance. Finally, extending the simulation to 36 or 48 hours after the maneuver is completed would give a better picture of the filter performance.

Appendix A Case Descriptions with Variables

Case #	Number of Measurements				Maneuver Direction	Maneuver Magnitude	Time of Maneuver	Drift Time	*i*
	Pass #1	Pass #2	Pass #3	Pass #4					
1	18	27	30	15	NA	0	NA	NA	45°
2	21	21	15	24	NA	0	NA	NA	90°
3	9	15	15	9	NA	0	NA	NA	45°

Case #	Number of Measurements				Maneuver Direction	Maneuver Magnitude	Time of Maneuver	Drift Time	*i*
	Pass #1	Pass #2	Pass #3	Pass #4					
1a	18	27	30	15	Radial	1 m/s	17:35:00	<10 hrs	45°
1b	18	27	27	15	Intrack	1 m/s	17:35:00	<10 hrs	45°
1c	18	27	30	15	Crosstrack	1 m/s	17:35:00	<10 hrs	45°
1d	18	27	30	15	Radial	5 m/s	17:35:00	<10 hrs	45°
1e	18	27	27	15	Intrack	5 m/s	17:35:00	<10 hrs	45°
1f	18	27	30	15	Crosstrack	5 m/s	17:35:00	<10 hrs	45°
1g	18	27	30	15	Radial	10 m/s	17:35:00	<10 hrs	45°
1h	18	27	30	18	Intrack	10 m/s	17:35:00	<10 hrs	45°
1i	18	27	30	15	Crosstrack	10 m/s	17:35:00	<10 hrs	45°
1j	18	27	30	15	Radial	1 m/s	19:20:00	>10 hrs	45°
1k	18	27	30	15	Intrack	1 m/s	19:20:00	>10 hrs	45°
1l	18	27	30	15	Crosstrack	1 m/s	19:20:00	>10 hrs	45°
1m	18	27	30	15	Radial	5 m/s	19:20:00	>10 hrs	45°
1n	18	27	30	15	Intrack	5 m/s	19:20:00	>10 hrs	45°
1o	18	27	30	15	Crosstrack	5 m/s	19:20:00	>10 hrs	45°
1p	18	27	30	18	Radial	10 m/s	19:20:00	>10 hrs	45°
1q	18	27	27	15	Intrack	10 m/s	19:20:00	>10 hrs	45°
1r	18	27	30	15	Crosstrack	10 m/s	19:20:00	>10 hrs	45°
1s	18	27	30	15	Radial	1 m/s	5:00:00	>10 hrs	45°
1t	18	27	30	15	Intrack	1 m/s	5:00:00	>10 hrs	45°
1u	18	27	30	15	Crosstrack	1 m/s	5:00:00	>10 hrs	45°
1v	18	27	30	15	Radial	5 m/s	5:00:00	>10 hrs	45°
1w	18	27	30	18	Intrack	5 m/s	5:00:00	>10 hrs	45°
1x	18	27	30	15	Crosstrack	5 m/s	5:00:00	>10 hrs	45°
1y	18	27	30	18	Radial	10 m/s	5:00:00	>10 hrs	45°
1z	18	27	30	15	Intrack	10 m/s	5:00:00	>10 hrs	45°
1aa	18	27	30	15	Crosstrack	10 m/s	5:00:00	>10 hrs	45°

Case #	Number of Measurements				Maneuver Direction	Maneuver Magnitude	Time of Maneuver	Drift Time	*i*
	Pass #1	Pass #2	Pass #3	Pass #4					
2a	21	18	15	24	Radial	5 m/s	17:40:00	<10 hrs	90°
2b	21	18	18	24	Intrack	5 m/s	17:40:00	<10 hrs	90°
2c	21	21	15	24	Crosstrack	5 m/s	17:40:00	<10 hrs	90°
2d	21	18	15	24	Radial	10 m/s	17:40:00	<10 hrs	90°
2e	21	21	18	24	Intrack	10 m/s	17:40:00	<10 hrs	90°
2f	21	21	15	24	Crosstrack	10 m/s	17:40:00	<10 hrs	90°
2g	21	21	15	24	Radial	5 m/s	19:20:00	>10 hrs	90°
2h	21	21	15	24	Intrack	5 m/s	19:20:00	>10 hrs	90°
2i	21	21	15	24	Crosstrack	5 m/s	19:20:00	>10 hrs	90°
2j	21	21	15	24	Radial	10 m/s	19:20:00	>10 hrs	90°
2k	21	21	18	27	Intrack	10 m/s	19:20:00	>10 hrs	90°
2l	21	21	15	24	Crosstrack	10 m/s	19:20:00	>10 hrs	90°
2m	21	21	15	24	Radial	5 m/s	5:00:00	>10 hrs	90°
2n	21	21	15	24	Intrack	5 m/s	5:00:00	>10 hrs	90°
2o	21	21	15	24	Crosstrack	5 m/s	5:00:00	>10 hrs	90°
2p	21	21	15	24	Radial	10 m/s	5:00:00	>10 hrs	90°
2q	21	21	15	24	Intrack	10 m/s	5:00:00	>10 hrs	90°
2r	21	21	15	24	Crosstrack	10 m/s	5:00:00	>10 hrs	90°

Case #	Number of Measurements				Maneuver Direction	Maneuver Magnitude	Time of Maneuver	Drift Time	*i*
	Pass #1	Pass #2	Pass #3	Pass #4					
3a	9	15	15	9	Radial	5 m/s	17:35:00	<10 hrs	45°
3b	9	15	9	3	Intrack	5 m/s	17:35:00	<10 hrs	45°
3c	9	15	15	9	Crosstrack	5 m/s	17:35:00	<10 hrs	45°
3d	9	15	15	9	Radial	10 m/s	17:35:00	<10 hrs	45°
3e	9	15	6	0	Intrack	10 m/s	17:35:00	<10 hrs	45°
3f	9	15	15	9	Crosstrack	10 m/s	17:35:00	<10 hrs	45°
3g	9	15	15	9	Radial	5 m/s	19:20:00	>10 hrs	45°
3h	9	15	16	3	Intrack	5 m/s	19:20:00	>10 hrs	45°
3i	9	15	15	9	Crosstrack	5 m/s	19:20:00	>10 hrs	45°
3j	9	15	15	9	Radial	10 m/s	19:20:00	>10 hrs	45°
3k	9	15	9	0	Intrack	10 m/s	19:20:00	>10 hrs	45°
3l	9	15	15	9	Crosstrack	10 m/s	19:20:00	>10 hrs	45°
3m	9	15	15	9	Radial	5 m/s	5:00:00	>10 hrs	45°
3n	9	15	15	9	Intrack	5 m/s	5:00:00	>10 hrs	45°
3o	9	15	15	9	Crosstrack	5 m/s	5:00:00	>10 hrs	45°
3p	9	15	15	9	Radial	10 m/s	5:00:00	>10 hrs	45°
3q	9	15	15	6	Intrack	10 m/s	5:00:00	>10 hrs	45°
3r	9	15	15	9	Crosstrack	10 m/s	5:00:00	>10 hrs	45°

Appendix B Measurement Residuals

Base Case Measurement Residuals

UTCG	Range (m)	Azimuth (°)	Elevation (°)
01 Jul 2011 17:27:00	-1,515.6889	1.259866	0.364521
01 Jul 2011 17:28:00	-34.4163	-0.132869	0.158043
01 Jul 2011 17:29:00	-31.3049	-0.140292	0.014911
01 Jul 2011 17:30:00	-15.9789	0.077528	-0.332998
01 Jul 2011 17:31:00	18.0778	-0.106232	0.165659
01 Jul 2011 17:32:00	-49.6745	-0.236762	0.070672
UTCG	**Range (m)**	**Azimuth (°)**	**Elevation (°)**
01 Jul 2011 19:05:00	-39.5999	0.971260	-0.494283
01 Jul 2011 19:06:00	12.0333	0.058801	-0.104511
01 Jul 2011 19:07:00	-29.1770	-0.218077	-0.139082
01 Jul 2011 19:08:00	-37.8105	0.032078	-0.151281
01 Jul 2011 19:09:00	-19.6249	0.181018	0.049036
01 Jul 2011 19:10:00	-14.3940	-0.007190	-0.120684
01 Jul 2011 19:11:00	30.1873	0.093718	0.023915
01 Jul 2011 19:12:00	-0.4185	0.074475	-0.002972
01 Jul 2011 19:13:00	28.8805	0.152718	-0.120014
UTCG	**Range (m)**	**Azimuth (°)**	**Elevation (°)**
02 Jul 2011 05:10:00	-205.0630	-0.671235	-0.626841
02 Jul 2011 05:11:00	-45.6404	-0.008876	0.092111
02 Jul 2011 05:12:00	-17.6006	-0.050516	-0.070318
02 Jul 2011 05:13:00	-23.4734	0.018967	0.068544
02 Jul 2011 05:14:00	-21.6794	-0.002297	0.026781
02 Jul 2011 05:15:00	53.6735	0.039300	0.114405
02 Jul 2011 05:16:00	18.5461	-0.329549	-0.088683
02 Jul 2011 05:17:00	3.0637	0.016570	0.011442
02 Jul 2011 05:18:00	5.3337	-0.166425	0.092436
02 Jul 2011 05:19:00	-58.5361	0.307818	0.087467
UTCG	**Range (m)**	**Azimuth (°)**	**Elevation (°)**
02 Jul 2011 06:51:00	-44.4154	-0.471530	-0.612512
02 Jul 2011 06:52:00	42.0113	0.126969	-0.105739
02 Jul 2011 06:53:00	38.3781	-0.013853	-0.005319
02 Jul 2011 06:54:00	14.7825	0.062012	-0.207741
02 Jul 2011 06:55:00	-6.0191	0.127382	-0.327401

Case 1b (1 m/s intrack maneuver at 17:35) Measurement Residuals

UTCG	Range (m)	Azimuth (°)	Elevation (°)
01 Jul 2011 17:27:00	-1,515.6889	1.259866	0.364521
01 Jul 2011 17:28:00	-34.4163	-0.132869	0.158043
01 Jul 2011 17:29:00	-31.3049	-0.140292	0.014911
01 Jul 2011 17:30:00	-15.9789	0.077528	-0.332998
01 Jul 2011 17:31:00	18.0778	-0.106232	0.165659
01 Jul 2011 17:32:00	-49.6745	-0.236762	0.070672
UTCG	**Range (m)**	**Azimuth (°)**	**Elevation (°)**
01 Jul 2011 19:05:00	47.1983	1.326808	0.912178
01 Jul 2011 19:06:00	-6.5583	0.165800	0.168023
01 Jul 2011 19:07:00	-28.7074	0.218716	-0.010560
01 Jul 2011 19:08:00	-4.0906	0.027587	-0.432699
01 Jul 2011 19:09:00	-15.5449	-0.051518	-0.022503
01 Jul 2011 19:10:00	10.2546	0.023684	0.149313
01 Jul 2011 19:11:00	2.9932	0.088397	-0.039956
01 Jul 2011 19:12:00	8.4003	0.146669	-0.136323
01 Jul 2011 19:13:00	20.5084	-0.068633	-0.037090
UTCG	**Range (m)**	**Azimuth (°)**	**Elevation (°)**
02 Jul 2011 05:11:00	-347.6934	0.921459	-0.497060
02 Jul 2011 05:12:00	25.6349	-0.344037	-0.069837
02 Jul 2011 05:13:00	13.7202	0.050931	0.163368
02 Jul 2011 05:14:00	-7.1942	0.042399	-0.105059
02 Jul 2011 05:15:00	-44.0637	0.098735	0.037160
02 Jul 2011 05:16:00	30.7000	-0.001259	0.256845
02 Jul 2011 05:17:00	37.0414	0.205360	0.251498
02 Jul 2011 05:18:00	-18.4101	0.105510	-0.327090
02 Jul 2011 05:19:00	44.9459	0.053630	-0.078559
UTCG	**Range (m)**	**Azimuth (°)**	**Elevation (°)**
02 Jul 2011 06:52:00	-74.5317	-0.702800	0.546252
02 Jul 2011 06:53:00	-33.4763	-0.150375	-0.028551
02 Jul 2011 06:54:00	3.3979	-0.132430	-0.289905
02 Jul 2011 06:55:00	4.5360	0.221891	0.090875
02 Jul 2011 06:56:00	-13.0763	0.050162	0.186352

Case 1e (5 m/s intrack maneuver at 17:35) Measurement Residuals

UTCG	Range (m)	Azimuth (°)	Elevation (°)
01 Jul 2011 17:27:00	-1,515.6889	1.259866	0.364521
01 Jul 2011 17:28:00	-34.4163	-0.132869	0.158043
01 Jul 2011 17:29:00	-31.3049	-0.140292	0.014911
01 Jul 2011 17:30:00	-15.9789	0.077528	-0.332998
01 Jul 2011 17:31:00	18.0778	-0.106232	0.165659
01 Jul 2011 17:32:00	-49.6745	-0.236762	0.070672
UTCG	**Range (m)**	**Azimuth (°)**	**Elevation (°)**
01 Jul 2011 19:05:00	324.7344	1.330075	0.910790
01 Jul 2011 19:06:00	-6.0479	0.166780	0.169383
01 Jul 2011 19:07:00	-27.7540	0.221969	-0.010397
01 Jul 2011 19:08:00	-1.9164	0.028367	-0.432573
01 Jul 2011 19:09:00	-13.9994	-0.051100	-0.021991
01 Jul 2011 19:10:00	10.2455	0.022663	0.149344
01 Jul 2011 19:11:00	1.6241	0.087577	-0.040098
01 Jul 2011 19:12:00	6.8997	0.146165	-0.136475
01 Jul 2011 19:13:00	18.9420	-0.068472	-0.037147
UTCG	**Range (m)**	**Azimuth (°)**	**Elevation (°)**
02 Jul 2011 05:12:00	-332.3191	1.094924	-0.395034
02 Jul 2011 05:13:00	-43.9034	-0.018871	-0.016813
02 Jul 2011 05:14:00	-4.3734	0.039994	-0.330333
02 Jul 2011 05:15:00	-35.4191	0.120398	0.063292
02 Jul 2011 05:16:00	-18.4190	0.049673	-0.155987
02 Jul 2011 05:17:00	11.0336	0.012697	0.268452
02 Jul 2011 05:18:00	-32.3177	0.073539	-0.005004
02 Jul 2011 05:19:00	3.7946	0.216680	0.163928
02 Jul 2011 05:20:00	16.5803	0.008295	0.054866
UTCG	**Range (m)**	**Azimuth (°)**	**Elevation (°)**
02 Jul 2011 06:53:00	-88.2862	-0.817819	0.886364
02 Jul 2011 06:54:00	-29.0648	0.171780	0.066350
02 Jul 2011 06:55:00	-23.8593	0.145713	0.328323
02 Jul 2011 06:56:00	-61.2776	-0.002070	-0.090174
02 Jul 2011 06:57:00	12.6430	0.085071	-0.022122

Case 1h (10 m/s intrack maneuver at 17:35) Measurement Residuals

UTCG	Range (m)	Azimuth (°)	Elevation (°)
01 Jul 2011 17:27:00	-1,515.6889	1.259866	0.364521
01 Jul 2011 17:28:00	-34.4163	-0.132869	0.158043
01 Jul 2011 17:29:00	-31.3049	-0.140292	0.014911
01 Jul 2011 17:30:00	-15.9789	0.077528	-0.332998
01 Jul 2011 17:31:00	18.0778	-0.106232	0.165659
01 Jul 2011 17:32:00	-49.6745	-0.236762	0.070672
UTCG	**Range (m)**	**Azimuth (°)**	**Elevation (°)**
01 Jul 2011 19:05:00	678.1608	1.333550	0.908560
01 Jul 2011 19:06:00	-5.7957	0.167842	0.171475
01 Jul 2011 19:07:00	-27.4030	0.225516	-0.010308
01 Jul 2011 19:08:00	-2.6599	0.029357	-0.432553
01 Jul 2011 19:09:00	-14.9718	-0.051085	-0.021501
01 Jul 2011 19:10:00	10.6102	0.021406	0.149450
01 Jul 2011 19:11:00	1.1660	0.086338	-0.040247
01 Jul 2011 19:12:00	6.2679	0.145418	-0.136619
01 Jul 2011 19:13:00	18.2949	-0.068245	-0.037184
UTCG	**Range (m)**	**Azimuth (°)**	**Elevation (°)**
02 Jul 2011 05:13:00	-321.8456	1.067930	-0.511390
02 Jul 2011 05:14:00	4.7865	-0.041750	-0.140296
02 Jul 2011 05:15:00	-7.0746	-0.155308	0.057243
02 Jul 2011 05:16:00	-35.6861	-0.107527	0.057384
02 Jul 2011 05:17:00	-19.8274	-0.023525	0.081550
02 Jul 2011 05:18:00	29.5209	-0.204653	0.082424
02 Jul 2011 05:19:00	3.2682	0.032453	-0.000349
02 Jul 2011 05:20:00	5.9430	0.028325	-0.008059
02 Jul 2011 05:21:00	-52.4167	-0.103799	-0.059816
02 Jul 2011 05:22:00	-4.9890	-0.114499	-0.101514
UTCG	**Range (m)**	**Azimuth (°)**	**Elevation (°)**
02 Jul 2011 06:54:00	-49.5298	-0.125285	Low El
02 Jul 2011 06:55:00	-27.4524	0.139683	-1.273290
02 Jul 2011 06:56:00	-68.8658	-0.002174	-0.123729
02 Jul 2011 06:57:00	2.3168	0.084893	-0.024036
02 Jul 2011 06:58:00	-41.3269	-0.103179	-0.012218
02 Jul 2011 06:59:00	18.5335	-0.072666	Low El

Appendix C Case Results

Case 1 Variants

Case 1a Tables

Table 1 Case1a Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.13	64.12	0.16	57.62	8.16	0.08
Pass 3	39.14	90.77	0.48	87.69	33.07	0.00
Pass 4	3.77	17.45	4.38	15.50	1.94	0.03

Table 2 Case 1a Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	**Radial**	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.220	144.497	19.671	27.36	3.52	2.14
01 Jul 2011 19:05:00	29.043	51.846	19.640	11.60	3.23	2.14
02 Jul 2011 05:10:00	50.204	604.623	21.273	64.19	5.33	2.24
02 Jul 2011 05:10:00	30.555	55.788	21.170	7.90	3.57	2.24
02 Jul 2011 06:51:00	21.640	70.315	20.680	11.91	2.38	2.31
02 Jul 2011 06:51:00	20.823	58.047	19.774	10.06	2.33	2.31

Table 3 Case 1a Classical Element Percentages

	Semi-Major Axis	**Eccentricity**	**True Arg of Lat**	**Inclination**	**RAAN**	**Arg of Perigee**
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	50.98	0.15	60.78	0.07	0.16	37.71
Pass 3	43.42	8.78	90.40	0.14	0.37	27.23
Pass 4	13.53	7.37	11.51	0.16	4.29	1.91

Table 4 Case 1a Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.83	0.000004341	0.001213683	0.000160949	0.000232228	0.494948
01 Jul 2011 19:05:00	6.29	0.000004334	0.000476029	0.000160832	0.000231858	0.308297
02 Jul 2011 05:10:00	10.79	0.000005678	0.005054322	0.000173143	0.000244655	0.697796
02 Jul 2011 05:10:00	6.11	0.000005180	0.000485198	0.000172908	0.000243751	0.507815
02 Jul 2011 06:51:00	6.70	0.000006721	0.000602980	0.000174819	0.000242436	1.785363
02 Jul 2011 06:51:00	5.79	0.000006226	0.000533548	0.000174539	0.000232040	1.819471

Case 1b Tables

Table 5 Case1b Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	7.44	75.13	0.05	61.38	0.32	0.04
Pass 3	35.19	90.50	0.51	84.41	29.30	0.00
Pass 4	6.21	14.78	5.41	13.14	4.07	0.00

Table 6 Case 1b Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	33.998	223.324	19.668	32.90	3.61	2.14
01 Jul 2011 19:05:00	31.467	55.537	19.658	12.70	3.60	2.14
02 Jul 2011 05:11:00	51.507	602.061	21.238	63.68	5.54	2.25
02 Jul 2011 05:11:00	33.381	57.190	21.131	9.93	3.92	2.25
02 Jul 2011 06:52:00	22.762	76.348	20.651	14.72	2.44	2.32
02 Jul 2011 06:52:00	21.348	65.064	19.533	12.78	2.34	2.32

Table 7 Case 1b Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	65.55	1.24	72.91	0.03	0.05	13.99
Pass 3	38.30	6.82	90.20	0.13	0.40	21.56
Pass 4	11.67	9.36	9.62	0.04	5.40	1.47

Table 8 Case 1b Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	21.95	0.000005201	0.001869806	0.000160905	0.000232182	0.443391
01 Jul 2011 19:05:00	7.56	0.000005137	0.000506619	0.000160850	0.000232057	0.381372
02 Jul 2011 05:11:00	10.90	0.000008443	0.005031512	0.000173303	0.000245033	0.576711
02 Jul 2011 05:11:00	6.72	0.000007867	0.000493187	0.000173086	0.000244046	0.452358
02 Jul 2011 06:52:00	7.17	0.000008515	0.000647340	0.000175041	0.000242564	1.030435
02 Jul 2011 06:52:00	6.33	0.000007717	0.000585076	0.000174972	0.000229461	1.015313

Case 1c Tables

Table 9 Case 1c Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.22	64.05	0.15	57.69	8.20	0.07
Pass 3	39.21	90.75	0.47	87.70	33.16	0.00
Pass 4	3.85	17.32	4.55	15.41	2.02	0.10

Table 10 Case 1c Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	**Radial**	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.127	144.161	19.840	27.31	3.51	2.34
01 Jul 2011 19:05:00	28.935	51.820	19.809	11.55	3.22	2.34
02 Jul 2011 05:10:00	49.644	602.661	22.369	64.00	5.27	2.33
02 Jul 2011 05:10:00	30.177	55.773	22.263	7.87	3.52	2.33
02 Jul 2011 06:51:00	21.593	70.044	21.001	11.85	2.37	2.48
02 Jul 2011 06:51:00	20.761	57.911	20.046	10.02	2.33	2.47

Table 11 Case 1c Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	50.89	2.93	60.65	0.07	0.16	37.76
Pass 3	43.54	12.95	90.37	0.14	0.38	27.34
Pass 4	13.39	6.66	11.28	0.27	4.45	3.92

Table 12 Case 1c Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.79	0.000004415	0.001211114	0.000175691	0.000234495	0.503970
01 Jul 2011 19:05:00	6.28	0.000004286	0.000476599	0.000175573	0.000234123	0.313648
02 Jul 2011 05:10:00	10.75	0.000006542	0.005038801	0.000186913	0.000247186	0.579214
02 Jul 2011 05:10:00	6.07	0.000005694	0.000485147	0.000186653	0.000246254	0.420876
02 Jul 2011 06:51:00	6.66	0.000006518	0.000600850	0.000188231	0.000244702	0.867539
02 Jul 2011 06:51:00	5.77	0.000006084	0.000533075	0.000187732	0.000233819	0.833548

Case 1d Tables

Table 13 Case 1d Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	7.49	73.34	0.07	57.60	0.91	0.04
Pass 3	35.10	91.01	0.44	84.75	29.81	0.00
Pass 4	3.56	20.17	4.25	17.31	1.51	0.02

Table 14 Case 1d Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	36.580	207.888	19.799	32.23	3.88	2.29
01 Jul 2011 19:05:00	33.838	55.430	19.786	13.67	3.85	2.29
02 Jul 2011 05:10:00	64.873	632.936	22.131	66.60	7.03	2.31
02 Jul 2011 05:10:00	42.101	56.928	22.034	10.16	4.93	2.31
02 Jul 2011 06:51:00	22.990	78.519	21.020	15.19	2.55	2.44
02 Jul 2011 06:51:00	22.172	62.685	20.127	12.56	2.51	2.44

Table 15 Case 1d Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	63.24	11.58	70.93	0.04	0.07	13.58
Pass 3	35.70	17.98	90.67	0.10	0.37	17.51
Pass 4	16.18	7.61	14.21	0.13	4.21	13.41

Table 16 Case 1d Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	20.21	0.000007036	0.001741594	0.000172155	0.000233966	0.451882
01 Jul 2011 19:05:00	7.43	0.000006221	0.000506255	0.000172093	0.000233806	0.390517
02 Jul 2011 05:10:00	11.24	0.000005167	0.005288108	0.000183887	0.000247173	1.078212
02 Jul 2011 05:10:00	7.23	0.000004238	0.000493481	0.000183694	0.000246253	0.889444
02 Jul 2011 06:51:00	7.57	0.000008987	0.000669476	0.000185472	0.000245155	0.754924
02 Jul 2011 06:51:00	6.34	0.000008303	0.000574314	0.000185235	0.000234831	0.653681

Case 1e Tables

Table 17 Case 1e Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	2.61	93.41	0.04	85.95	32.84	0.00
Pass 3	33.62	90.25	0.52	82.66	28.64	0.00
Pass 4	6.42	17.55	5.21	15.53	4.06	0.01

Table 18 Case 1e Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	33.859	881.289	19.812	97.32	5.69	2.29
01 Jul 2011 19:05:00	32.977	58.099	19.803	13.68	3.82	2.29
02 Jul 2011 05:12:00	53.479	586.258	21.970	61.65	5.83	2.32
02 Jul 2011 05:12:00	35.498	57.144	21.857	10.69	4.16	2.32
02 Jul 2011 06:53:00	22.565	77.002	20.893	15.67	2.42	2.43
02 Jul 2011 06:53:00	21.116	63.486	19.805	13.23	2.32	2.43

Table 19 Case 1e Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	90.84	52.69	92.83	0.00	0.04	0.16
Pass 3	34.53	3.25	89.94	0.12	0.43	18.46
Pass 4	14.09	11.94	11.88	0.06	5.21	7.54

Table 20 Case 1e Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	91.69	0.000013887	0.007362520	0.000171945	0.000233891	0.299286
01 Jul 2011 19:05:00	8.40	0.000006570	0.000528187	0.000171942	0.000233788	0.298798
02 Jul 2011 05:12:00	10.43	0.000007395	0.004892082	0.000183163	0.000246139	0.339532
02 Jul 2011 05:12:00	6.83	0.000007154	0.000492369	0.000182936	0.000245081	0.276861
02 Jul 2011 06:53:00	7.17	0.000006727	0.000649774	0.000184636	0.000243894	0.384323
02 Jul 2011 06:53:00	6.16	0.000005924	0.000572590	0.000184521	0.000231177	0.355328

Case 1f Tables

Table 21 Case 1f Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	8.55	73.29	0.07	60.20	0.98	0.03
Pass 3	34.37	90.63	0.50	84.90	28.55	0.09
Pass 4	5.36	19.13	7.50	16.21	2.97	2.59

Table 22 Case 1f Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.209	206.644	23.655	31.63	3.60	5.24
01 Jul 2011 19:05:00	31.286	55.202	23.638	12.59	3.57	5.24
02 Jul 2011 05:10:00	53.884	605.293	41.075	64.26	5.81	3.90
02 Jul 2011 05:10:00	35.363	56.705	40.871	9.70	4.15	3.90
02 Jul 2011 06:51:00	22.138	75.737	27.587	14.45	2.42	4.98
02 Jul 2011 06:51:00	20.952	61.251	25.517	12.11	2.34	4.85

Table 23 Case 1f Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	63.07	0.87	69.87	0.03	0.07	16.57
Pass 3	39.07	8.28	90.28	0.26	0.55	22.18
Pass 4	14.89	8.07	10.78	2.95	7.34	5.20

Table 24 Case 1f Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	20.09	0.000004922	0.001734939	0.000391978	0.000284735	0.505291
01 Jul 2011 19:05:00	7.42	0.000004880	0.000522811	0.000391853	0.000284530	0.421581
02 Jul 2011 05:10:00	11.05	0.000008901	0.005068035	0.000397067	0.000303214	0.664069
02 Jul 2011 05:10:00	6.73	0.000008164	0.000492441	0.000396029	0.000301553	0.516792
02 Jul 2011 06:51:00	7.19	0.000009118	0.000648785	0.000387511	0.000293375	1.019123
02 Jul 2011 06:51:00	6.12	0.000008382	0.000578825	0.000376096	0.000271841	0.966119

Case 1g Tables

Table 25 Case 1g Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	2.57	82.54	0.01	61.08	1.05	0.01
Pass 3	38.84	91.67	0.33	83.69	34.50	0.00
Pass 4	2.61	21.58	4.12	18.28	0.81	0.11

Table 26 Case 1g Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	43.166	335.188	20.196	43.95	4.85	2.71
01 Jul 2011 19:05:00	42.057	58.527	20.193	17.10	4.79	2.71
02 Jul 2011 05:10:00	91.375	703.782	24.595	72.49	9.99	2.51
02 Jul 2011 05:10:00	55.886	58.613	24.514	11.82	6.55	2.51
02 Jul 2011 06:51:00	24.847	84.797	21.929	17.16	2.80	2.80
02 Jul 2011 06:51:00	24.198	66.500	21.025	14.02	2.78	2.80

Table 27 Case 1g Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	76.11	9.08	80.98	0.01	0.01	1.27
Pass 3	26.97	30.06	91.36	0.07	0.32	17.60
Pass 4	17.44	9.22	15.51	0.26	4.10	13.30

Table 28 Case 1g Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	34.11	0.000012899	0.002804196	0.000203267	0.000239254	0.395682
01 Jul 2011 19:05:00	8.15	0.000011728	0.000533284	0.000203242	0.000239228	0.390652
02 Jul 2011 05:10:00	11.59	0.000013924	0.005874384	0.000213399	0.000253260	0.639931
02 Jul 2011 05:10:00	8.46	0.000009738	0.000507811	0.000213240	0.000252440	0.527280
02 Jul 2011 06:51:00	8.30	0.000010861	0.000724496	0.000214500	0.000251874	0.306472
02 Jul 2011 06:51:00	6.85	0.000009859	0.000612115	0.000213944	0.000241537	0.265724

Case 1h Tables

Table 29 Case 1h Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	6.34	96.70	0.27	92.67	60.61	0.00
Pass 3	33.26	90.07	0.50	82.15	29.32	0.00
Pass 4	4.62	20.56	4.80	17.93	2.47	0.09

Table 30 Case 1h Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.920	1,754.331	20.318	189.49	9.60	2.70
01 Jul 2011 19:05:00	32.705	57.842	20.264	13.89	3.78	2.70
02 Jul 2011 05:13:00	55.606	570.405	24.331	59.59	6.11	2.50
02 Jul 2011 05:13:00	37.110	56.648	24.210	10.64	4.32	2.50
02 Jul 2011 06:54:00	21.616	74.434	21.777	15.43	2.34	2.76
02 Jul 2011 06:54:00	20.617	59.128	20.731	12.67	2.28	2.76

Table 31 Case 1h Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	95.43	73.11	96.40	0.00	0.27	0.91
Pass 3	32.39	2.34	89.70	0.14	0.45	19.04
Pass 4	16.53	12.86	14.03	0.26	4.81	9.63

Table 32 Case 1h Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	182.65	0.000026598	0.014653326	0.000202847	0.000239462	0.213708
01 Jul 2011 19:05:00	8.35	0.000007152	0.000527245	0.000202847	0.000238813	0.211760
02 Jul 2011 05:13:00	9.80	0.000006689	0.004751207	0.000211857	0.000250693	0.212623
02 Jul 2011 05:13:00	6.63	0.000006533	0.000489362	0.000211567	0.000249562	0.172134
02 Jul 2011 06:54:00	6.90	0.000006283	0.000628186	0.000212685	0.000248751	0.198709
02 Jul 2011 06:54:00	5.76	0.000005475	0.000540025	0.000212129	0.000236795	0.179579

Case 1i Tables

Table 33 Case 1i Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	4.16	82.70	0.03	68.48	1.79	0.03
Pass 3	32.70	90.46	0.92	83.74	27.12	0.53
Pass 4	7.48	18.68	13.62	14.66	4.70	8.87

Table 34 Case 1i Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	76.05	15.44	78.73	0.03	0.03	4.62
Pass 3	36.81	7.67	90.10	0.72	1.01	20.96
Pass 4	13.69	6.64	6.44	9.25	13.43	6.50

Table 35 Case 1i Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	33.97	0.000006247	0.002797841	0.000732982	0.000403426	0.509388
01 Jul 2011 19:05:00	8.14	0.000005282	0.000595235	0.000732747	0.000403298	0.485852
02 Jul 2011 05:10:00	11.18	0.000009846	0.005129250	0.000734748	0.000432849	0.709321
02 Jul 2011 05:10:00	7.07	0.000009091	0.000507871	0.000729491	0.000428490	0.560677
02 Jul 2011 06:51:00	7.44	0.000010134	0.000683206	0.000669224	0.000392363	1.076012
02 Jul 2011 06:51:00	6.42	0.000009461	0.000639240	0.000607339	0.000339675	1.006121

Case 1j Tables

Table 36 Case 1j Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.124	140.955	19.665	27.11	3.50	2.14
01 Jul 2011 19:05:00	28.744	51.546	19.633	11.47	3.19	2.13
02 Jul 2011 05:10:00	50.135	629.842	21.296	67.22	5.31	2.24
02 Jul 2011 05:10:00	31.588	56.015	21.198	7.84	3.67	2.24
02 Jul 2011 06:51:00	22.191	69.513	20.722	11.64	2.45	2.31
02 Jul 2011 06:51:00	21.366	57.633	19.805	9.89	2.40	2.31

Table 37 Case 1j Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	50.12	3.58	60.01	0.08	0.17	39.77
Pass 3	45.88	7.46	90.75	0.12	0.37	25.08
Pass 4	13.08	8.14	11.14	0.17	4.32	0.12

Table 38 Case 1j Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.40	0.000004393	0.001184219	0.000160470	0.000232148	0.503914
01 Jul 2011 19:05:00	6.18	0.000004236	0.000473517	0.000160348	0.000231760	0.303517
02 Jul 2011 05:10:00	11.13	0.000005421	0.005264173	0.000172797	0.000245062	0.601714
02 Jul 2011 05:10:00	6.02	0.000005016	0.000487023	0.000172590	0.000244164	0.450812
02 Jul 2011 06:51:00	6.61	0.000006129	0.000596817	0.000174488	0.000242894	1.315889
02 Jul 2011 06:51:00	5.75	0.000005630	0.000530307	0.000174184	0.000232392	1.317520

Case 1k Tables

Table 39 Case 1k Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.124	140.955	19.665	27.11	3.50	2.14
01 Jul 2011 19:05:00	28.744	51.546	19.633	11.47	3.19	2.13
02 Jul 2011 05:10:00	52.099	1,189.435	21.299	132.15	5.35	2.24
02 Jul 2011 05:10:00	39.315	57.592	21.226	9.24	4.52	2.24
02 Jul 2011 06:52:00	22.017	69.315	20.656	12.46	2.40	2.31
02 Jul 2011 06:52:00	21.016	61.142	19.540	11.30	2.33	2.31

Table 40 Case 1k Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	50.12	3.58	60.01	0.08	0.17	39.77
Pass 3	69.68	0.64	94.98	0.00	0.51	5.49
Pass 4	8.75	3.75	6.87	0.11	5.36	0.25

Table 41 Case 1k Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.40	0.000004393	0.001184219	0.000160470	0.000232148	0.503914
01 Jul 2011 19:05:00	6.18	0.000004236	0.000473517	0.000160348	0.000231760	0.303517
02 Jul 2011 05:10:00	19.89	0.000006918	0.009927124	0.000172710	0.000245318	0.406296
02 Jul 2011 05:10:00	6.03	0.000006873	0.000498541	0.000172713	0.000244071	0.383972
02 Jul 2011 06:52:00	6.51	0.000008104	0.000594492	0.000174452	0.000242628	0.504737
02 Jul 2011 06:52:00	5.94	0.000007800	0.000553657	0.000174253	0.000229631	0.503457

Case 1l Tables

Table 42 Case 1l Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.124	140.955	19.665	27.11	3.50	2.14
01 Jul 2011 19:05:00	28.744	51.546	19.633	11.47	3.19	2.13
02 Jul 2011 05:10:00	49.289	627.793	23.112	67.00	5.22	2.24
02 Jul 2011 05:10:00	30.693	55.953	23.019	7.84	3.57	2.24
02 Jul 2011 06:51:00	21.646	69.291	22.128	11.62	2.38	2.34
02 Jul 2011 06:51:00	20.831	57.627	21.042	9.90	2.34	2.34

Table 43 Case 1l Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	50.12	3.58	60.01	0.08	0.17	39.77
Pass 3	45.91	11.74	90.69	0.12	0.33	25.31
Pass 4	12.87	5.83	10.33	0.31	4.82	5.18

Table 44 Case 1l Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.40	0.000004393	0.001184219	0.000160470	0.000232148	0.503914
01 Jul 2011 19:05:00	6.18	0.000004236	0.000473517	0.000160348	0.000231760	0.303517
02 Jul 2011 05:10:00	11.08	0.000006250	0.005248147	0.000177097	0.000261288	0.569472
02 Jul 2011 05:10:00	6.00	0.000005516	0.000488661	0.000176892	0.000260429	0.425329
02 Jul 2011 06:51:00	6.58	0.000006429	0.000597950	0.000178523	0.000257831	0.857245
02 Jul 2011 06:51:00	5.73	0.000006055	0.000536204	0.000177973	0.000245410	0.812811

Case 1m Tables

Table 45 Case 1m Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.77	63.43	0.16	57.69	8.91	0.08
Pass 3	17.98	94.47	0.31	92.27	12.09	0.10
Pass 4	4.02	16.90	5.02	13.36	2.53	0.11

Table 46 Case 1m Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.124	140.955	19.665	27.11	3.50	2.14
01 Jul 2011 19:05:00	28.744	51.546	19.633	11.47	3.19	2.13
02 Jul 2011 05:10:00	68.559	1,090.358	22.705	120.68	7.29	2.24
02 Jul 2011 05:10:00	56.229	60.283	22.634	9.33	6.41	2.24
02 Jul 2011 06:51:00	29.195	70.782	21.957	12.51	3.25	2.34
02 Jul 2011 06:51:00	28.020	58.821	20.854	10.83	3.17	2.33

Table 47 Case 1m Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	50.12	3.58	60.01	0.08	0.17	39.77
Pass 3	64.98	6.21	94.27	0.00	0.42	3.17
Pass 4	12.20	0.64	10.48	0.32	4.91	5.15

Table 48 Case 1m Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.40	0.000004393	0.001184219	0.000160470	0.000232148	0.503914
01 Jul 2011 19:05:00	6.18	0.000004236	0.000473517	0.000160348	0.000231760	0.303517
02 Jul 2011 05:10:00	18.39	0.000006416	0.009097405	0.000176086	0.000257795	0.538174
02 Jul 2011 05:10:00	6.44	0.000006017	0.000521390	0.000176082	0.000256708	0.521097
02 Jul 2011 06:51:00	6.79	0.000004509	0.000609939	0.000177835	0.000255881	0.837709
02 Jul 2011 06:51:00	5.96	0.000004480	0.000546022	0.000177264	0.000243318	0.794538

Case 1n Tables

Table 49 Case 1n Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.77	63.43	0.16	57.69	8.91	0.08
Pass 3	53.46	98.88	1.75	98.33	32.94	4.64
Pass 4	4.11	11.98	5.71	9.30	2.69	0.11

Table 50 Case 1n Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.124	140.955	19.665	27.11	3.50	2.14
01 Jul 2011 19:05:00	28.744	51.546	19.633	11.47	3.19	2.13
02 Jul 2011 05:11:00	91.217	5,196.444	22.970	584.37	7.27	2.34
02 Jul 2011 05:11:00	42.454	58.450	22.569	9.75	4.87	2.23
02 Jul 2011 06:53:00	22.275	68.065	21.701	12.77	2.44	2.33
02 Jul 2011 06:53:00	21.360	59.913	20.463	11.58	2.38	2.33

Table 51 Case 1n Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	50.12	3.58	60.01	0.08	0.17	39.77
Pass 3	92.97	49.57	98.83	1.08	4.81	1.33
Pass 4	8.82	4.69	6.58	0.23	5.65	0.31

Table 52 Case 1n Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.40	0.000004393	0.001184219	0.000160470	0.000232148	0.503914
01 Jul 2011 19:05:00	6.18	0.000004236	0.000473517	0.000160348	0.000231760	0.303517
02 Jul 2011 05:11:00	85.44	0.000015250	0.043304293	0.000177377	0.000268421	0.191588
02 Jul 2011 05:11:00	6.01	0.000007690	0.000506156	0.000175452	0.000255507	0.189031
02 Jul 2011 06:53:00	6.29	0.000008034	0.000586102	0.000176868	0.000253654	0.182549
02 Jul 2011 06:53:00	5.73	0.000007657	0.000547525	0.000176462	0.000239313	0.183109

Case 1o Tables

Table 53 Case 1o Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.77	63.43	0.16	57.69	8.91	0.08
Pass 3	25.27	94.59	0.09	92.28	16.59	0.10
Pass 4	5.39	13.81	13.89	9.82	3.52	4.58

Table 54 Case 1o Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.124	140.955	19.665	27.11	3.50	2.14
01 Jul 2011 19:05:00	28.744	51.546	19.633	11.47	3.19	2.13
02 Jul 2011 05:10:00	51.932	1,081.511	50.337	119.79	5.36	2.24
02 Jul 2011 05:10:00	38.811	58.525	50.292	9.24	4.47	2.24
02 Jul 2011 06:51:00	23.008	69.684	42.247	12.43	2.54	3.02
02 Jul 2011 06:51:00	21.768	60.062	36.378	11.21	2.46	2.88

Table 55 Case 1o Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	50.12	3.58	60.01	0.08	0.17	39.77
Pass 3	66.55	0.05	93.86	0.00	0.14	6.86
Pass 4	9.61	2.03	1.75	6.20	13.82	6.43

Table 56 Case 1o Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.40	0.000004393	0.001184219	0.000160470	0.000232148	0.503914
01 Jul 2011 19:05:00	6.18	0.000004236	0.000473517	0.000160348	0.000231760	0.303517
02 Jul 2011 05:10:00	18.24	0.000006681	0.009034837	0.000261806	0.000521564	0.576169
02 Jul 2011 05:10:00	6.10	0.000006678	0.000554906	0.000261796	0.000520859	0.536666
02 Jul 2011 06:51:00	6.62	0.000008048	0.000661745	0.000248969	0.000476476	0.898326
02 Jul 2011 06:51:00	5.98	0.000007884	0.000650139	0.000233523	0.000410616	0.840531

Case 1p Tables

Table 57 Case 1p Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.77	63.43	0.16	57.69	8.91	0.08
Pass 3	12.38	96.39	0.30	95.13	6.90	0.54
Pass 4	4.82	16.62	6.41	12.68	3.32	0.40

Table 58 Case 1p Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.124	140.955	19.665	27.11	3.50	2.14
01 Jul 2011 19:05:00	28.744	51.546	19.633	11.47	3.19	2.13
02 Jul 2011 05:10:00	107.287	1,909.348	26.620	213.76	11.44	2.25
02 Jul 2011 05:10:00	94.001	68.891	26.539	10.40	10.65	2.24
02 Jul 2011 06:51:00	33.918	72.177	25.250	12.85	3.79	2.42
02 Jul 2011 06:51:00	32.284	60.179	23.632	11.22	3.67	2.41

Table 59 Case 1p Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	50.12	3.58	60.01	0.08	0.17	39.77
Pass 3	76.79	6.14	96.26	0.05	0.66	0.76
Pass 4	11.34	0.23	8.93	0.84	6.29	5.36

Table 60 Case 1p Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.40	0.000004393	0.001184219	0.000160470	0.000232148	0.503914
01 Jul 2011 19:05:00	6.18	0.000004236	0.000473517	0.000160348	0.000231760	0.303517
02 Jul 2011 05:10:00	31.62	0.000012812	0.015913714	0.000186041	0.000293991	0.395327
02 Jul 2011 05:10:00	7.34	0.000012025	0.000594503	0.000185949	0.000292045	0.392317
02 Jul 2011 06:51:00	6.99	0.000005709	0.000628822	0.000187385	0.000290764	0.387954
02 Jul 2011 06:51:00	6.20	0.000005696	0.000572646	0.000185807	0.000272469	0.367161

Case 1q Tables

Table 61 Case 1q Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	50.12	3.58	60.01	0.08	0.17	39.77
Pass 3	96.42	72.17	99.40	3.54	11.58	3.38
Pass 4	0.00	0.00	0.00	0.00	0.00	0.00

Table 62 Case 1q Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.40	0.000004393	0.001184219	0.000160470	0.000232148	0.503914
01 Jul 2011 19:05:00	6.18	0.000004236	0.000473517	0.000160348	0.000231760	0.303517
02 Jul 2011 05:13:00	171.40	0.000028483	0.086466329	0.000191471	0.000327628	0.121554
02 Jul 2011 05:13:00	6.13	0.000007928	0.000520240	0.000184685	0.000289692	0.117441
02 Jul 2011 06:54:00	6.13	0.000007947	0.000590190	0.000185436	0.000286463	0.102556
02 Jul 2011 06:54:00	6.13	0.000007947	0.000590189	0.000185436	0.000286463	0.102555

Case 1r Tables

Table 63 Case 1r Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.124	140.955	19.665	27.11	3.50	2.14
01 Jul 2011 19:05:00	28.744	51.546	19.633	11.47	3.19	2.13
02 Jul 2011 05:10:00	59.435	1,895.532	93.711	212.52	5.77	2.25
02 Jul 2011 05:10:00	43.126	61.767	93.676	9.88	4.95	2.24
02 Jul 2011 06:51:00	25.529	69.879	66.059	12.72	2.84	4.03
02 Jul 2011 06:51:00	23.109	62.774	48.723	12.03	2.62	3.41

Table 64 Case 1r Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	50.12	3.58	60.01	0.08	0.17	39.77
Pass 3	80.32	10.26	95.57	0.00	0.09	1.43
Pass 4	5.69	0.16	0.80	18.04	26.19	8.22

Table 65 Case 1r Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.40	0.000004393	0.001184219	0.000160470	0.000232148	0.503914
01 Jul 2011 19:05:00	6.18	0.000004236	0.000473517	0.000160348	0.000231760	0.303517
02 Jul 2011 05:10:00	31.43	0.000007868	0.015829336	0.000429518	0.000953743	0.596658
02 Jul 2011 05:10:00	6.18	0.000007061	0.000701713	0.000429532	0.000952924	0.588111
02 Jul 2011 06:51:00	6.65	0.000008652	0.000771492	0.000348485	0.000739869	0.950854
02 Jul 2011 06:51:00	6.27	0.000008638	0.000765312	0.000285621	0.000546130	0.872725

Case 1s Tables

Table 66 Case 1s Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.77	63.43	0.16	57.69	8.91	0.08
Pass 3	39.40	90.73	0.48	87.99	33.41	0.00
Pass 4	4.06	19.32	4.21	17.43	1.96	0.04

Table 67 Case 1s Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.124	140.955	19.665	27.11	3.50	2.14
01 Jul 2011 19:05:00	28.744	51.546	19.633	11.47	3.19	2.13
02 Jul 2011 05:10:00	49.519	601.503	21.256	63.87	5.25	2.24
02 Jul 2011 05:10:00	30.010	55.743	21.153	7.67	3.49	2.24
02 Jul 2011 06:51:00	22.305	75.710	20.715	12.12	2.45	2.31
02 Jul 2011 06:51:00	21.399	61.084	19.843	10.01	2.40	2.31

Table 68 Case 1s Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	50.12	3.58	60.01	0.08	0.17	39.77
Pass 3	39.80	11.44	90.35	0.14	0.37	28.09
Pass 4	15.44	8.47	13.44	0.16	4.12	1.58

Table 69 Case 1s Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.40	0.000004393	0.001184219	0.000160470	0.000232148	0.503914
01 Jul 2011 19:05:00	6.18	0.000004236	0.000473517	0.000160348	0.000231760	0.303517
02 Jul 2011 05:10:00	11.26	0.000005960	0.005028442	0.000172734	0.000245112	0.514179
02 Jul 2011 05:10:00	6.78	0.000005278	0.000485082	0.000172494	0.000244212	0.369727
02 Jul 2011 06:51:00	7.32	0.000006210	0.000646728	0.000174417	0.000242937	0.720172
02 Jul 2011 06:51:00	6.19	0.000005684	0.000559821	0.000174137	0.000232933	0.731583

Case 1t Tables

Table 70 Case 1t Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.77	63.43	0.16	57.69	8.91	0.08
Pass 3	39.47	90.73	0.48	87.92	33.45	0.00
Pass 4	9.93	50.83	1.75	48.55	0.39	0.02

Table 71 Case 1t Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	50.12	3.58	60.01	0.08	0.17	39.77
Pass 3	9.14	18.05	90.36	0.14	0.37	23.32
Pass 4	48.59	14.65	46.98	0.09	1.70	1.16

Table 72 Case 1t Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.40	0.000004393	0.001184219	0.000160470	0.000232148	0.503914
01 Jul 2011 19:05:00	6.18	0.000004236	0.000473517	0.000160348	0.000231760	0.303517
02 Jul 2011 05:10:00	20.99	0.000007611	0.005028533	0.000172724	0.000245097	0.404923
02 Jul 2011 05:10:00	19.07	0.000006237	0.000484986	0.000172484	0.000244197	0.310496
02 Jul 2011 06:51:00	19.17	0.000006678	0.001547090	0.000174378	0.000242841	0.416759
02 Jul 2011 06:51:00	9.85	0.000005699	0.000820196	0.000174227	0.000238701	0.421598

Case 1u Tables

Table 73 Case 1u Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.77	63.43	0.16	57.69	8.91	0.08
Pass 3	39.87	90.74	0.43	88.02	33.84	0.00
Pass 4	4.02	19.04	4.62	17.07	1.89	0.00

Table 74 Case 1u Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.124	140.955	19.665	27.11	3.50	2.14
01 Jul 2011 19:05:00	28.744	51.546	19.633	11.47	3.19	2.13
02 Jul 2011 05:10:00	49.190	601.483	21.946	63.86	5.21	2.37
02 Jul 2011 05:10:00	29.576	55.707	21.851	7.65	3.45	2.37
02 Jul 2011 06:51:00	21.634	75.560	22.065	12.08	2.38	2.35
02 Jul 2011 06:51:00	20.765	61.171	21.044	10.01	2.33	2.35

Table 75 Case 1u Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	50.12	3.58	60.01	0.08	0.17	39.77
Pass 3	39.26	14.09	90.29	0.12	0.31	28.11
Pass 4	15.26	6.66	12.55	0.08	4.53	2.65

Table 76 Case 1u Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.40	0.000004393	0.001184219	0.000160470	0.000232148	0.503914
01 Jul 2011 19:05:00	6.18	0.000004236	0.000473517	0.000160348	0.000231760	0.303517
02 Jul 2011 05:10:00	11.14	0.000006238	0.005028904	0.000174668	0.000263952	0.570114
02 Jul 2011 05:10:00	6.76	0.000005359	0.000488351	0.000174461	0.000263128	0.409873
02 Jul 2011 06:51:00	7.31	0.000006197	0.000649030	0.000176452	0.000260526	0.853944
02 Jul 2011 06:51:00	6.19	0.000005784	0.000567605	0.000176302	0.000248736	0.831306

Case 1v Tables

Table 77 Case 1v Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.124	140.955	19.665	27.11	3.50	2.14
01 Jul 2011 19:05:00	28.744	51.546	19.633	11.47	3.19	2.13
02 Jul 2011 05:10:00	56.718	601.842	21.784	64.16	6.08	2.34
02 Jul 2011 05:10:00	39.400	56.795	21.683	8.22	4.52	2.34
02 Jul 2011 06:51:00	31.537	165.637	21.867	21.71	3.43	2.34
02 Jul 2011 06:51:00	29.435	90.329	21.349	12.14	3.39	2.34

Table 78 Case 1v Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	50.12	3.58	60.01	0.08	0.17	39.77
Pass 3	12.79	1.78	90.14	0.13	0.33	25.19
Pass 4	42.22	5.87	40.83	0.07	2.31	11.25

Table 79 Case 1v Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.40	0.000004393	0.001184219	0.000160470	0.000232148	0.503914
01 Jul 2011 19:05:00	6.18	0.000004236	0.000473517	0.000160348	0.000231760	0.303517
02 Jul 2011 05:10:00	19.40	0.000008079	0.005029994	0.000174246	0.000259420	0.367335
02 Jul 2011 05:10:00	16.92	0.000007935	0.000496068	0.000174012	0.000258559	0.274803
02 Jul 2011 06:51:00	17.12	0.000006564	0.001385738	0.000176055	0.000257618	0.452739
02 Jul 2011 06:51:00	9.89	0.000006178	0.000819964	0.000175932	0.000251677	0.401804

Case 1w Tables

Table 80 Case 1w Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.124	140.955	19.665	27.11	3.50	2.14
01 Jul 2011 19:05:00	28.744	51.546	19.633	11.47	3.19	2.13
02 Jul 2011 05:10:00	52.844	601.878	21.783	63.95	5.99	2.34
02 Jul 2011 05:10:00	35.990	56.458	21.682	9.23	4.46	2.34
02 Jul 2011 06:51:00	39.517	727.502	21.793	88.46	2.47	2.34
02 Jul 2011 06:51:00	21.243	100.566	21.632	12.93	2.44	2.34

Table 81 Case 1w Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	50.12	3.58	60.01	0.08	0.17	39.77
Pass 3	0.29	7.91	90.20	0.14	0.33	5.30
Pass 4	85.59	57.20	84.94	0.08	0.69	0.73

Table 82 Case 1w Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.40	0.000004393	0.001184219	0.000160470	0.000232148	0.503914
01 Jul 2011 19:05:00	6.18	0.000004236	0.000473517	0.000160348	0.000231760	0.303517
02 Jul 2011 05:10:00	91.23	0.000014998	0.005030902	0.000174196	0.000259330	0.199463
02 Jul 2011 05:10:00	90.96	0.000013811	0.000493183	0.000173960	0.000258469	0.188892
02 Jul 2011 06:51:00	76.18	0.000013160	0.006046142	0.000175889	0.000256727	0.145804
02 Jul 2011 06:51:00	10.98	0.000005633	0.000910712	0.000175745	0.000254946	0.144747

Case 1x Tables

Table 83 Case 1x Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.124	140.955	19.665	27.11	3.50	2.14
01 Jul 2011 19:05:00	28.744	51.546	19.633	11.47	3.19	2.13
02 Jul 2011 05:10:00	49.528	601.503	34.996	63.87	5.26	4.53
02 Jul 2011 05:10:00	30.103	56.046	34.935	7.74	3.52	4.53
02 Jul 2011 06:51:00	23.625	165.460	41.990	21.57	2.47	3.15
02 Jul 2011 06:51:00	21.265	97.025	39.021	13.16	2.44	3.09

Table 84 Case 1x Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	50.12	3.58	60.01	0.08	0.17	39.77
Pass 3	11.29	13.24	88.67	0.02	0.10	25.83
Pass 4	38.90	10.55	28.37	1.19	7.01	2.35

Table 85 Case 1x Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.40	0.000004393	0.001184219	0.000160470	0.000232148	0.503914
01 Jul 2011 19:05:00	6.18	0.000004236	0.000473517	0.000160348	0.000231760	0.303517
02 Jul 2011 05:10:00	19.04	0.000006421	0.005039866	0.000217797	0.000554209	0.591900
02 Jul 2011 05:10:00	16.89	0.000005571	0.000571263	0.000217746	0.000553676	0.438984
02 Jul 2011 06:51:00	17.07	0.000006646	0.001409036	0.000216555	0.000512917	0.900732
02 Jul 2011 06:51:00	10.43	0.000005945	0.001009312	0.000213982	0.000476951	0.921938

Case 1y Tables

Table 86 Case 1y Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	**Radial**	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.124	140.955	19.665	27.11	3.50	2.14
01 Jul 2011 19:05:00	28.744	51.546	19.633	11.47	3.19	2.13
02 Jul 2011 05:10:00	74.762	602.836	23.355	65.02	8.14	2.63
02 Jul 2011 05:10:00	59.743	59.928	23.259	9.73	6.77	2.63
02 Jul 2011 06:51:00	38.603	305.244	24.990	37.59	4.20	2.44
02 Jul 2011 06:51:00	35.802	105.698	24.662	13.19	4.20	2.44

Table 87 Case 1y Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	50.12	3.58	60.01	0.08	0.17	39.77
Pass 3	4.52	0.01	89.50	0.12	0.26	20.60
Pass 4	62.96	1.01	61.66	0.01	1.28	27.00

Table 88 Case 1y Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.40	0.000004393	0.001184219	0.000160470	0.000232148	0.503914
01 Jul 2011 19:05:00	6.18	0.000004236	0.000473517	0.000160348	0.000231760	0.303517
02 Jul 2011 05:10:00	33.71	0.000013734	0.005037349	0.000178838	0.000299839	0.282182
02 Jul 2011 05:10:00	32.19	0.000013732	0.000528883	0.000178619	0.000299065	0.224066
02 Jul 2011 06:51:00	32.04	0.000007538	0.002543785	0.000180722	0.000297538	0.311706
02 Jul 2011 06:51:00	11.87	0.000007462	0.000975281	0.000180712	0.000293734	0.227548

Case 1z Tables

Table 89 Case 1z Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.77	63.43	0.16	57.69	8.91	0.08
Pass 3	19.55	90.28	0.41	80.03	15.62	0.00
Pass 4	59.96	87.40	1.56	87.04	0.07	0.00

Table 90 Case 1z Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.124	140.955	19.665	27.11	3.50	2.14
01 Jul 2011 19:05:00	28.744	51.546	19.633	11.47	3.19	2.13
02 Jul 2011 05:10:00	62.878	603.048	23.353	64.29	7.85	2.63
02 Jul 2011 05:10:00	50.589	58.627	23.256	12.84	6.62	2.63
02 Jul 2011 06:52:00	56.567	1,072.354	24.994	130.09	2.62	2.42
02 Jul 2011 06:52:00	22.652	135.110	24.603	16.85	2.62	2.42

Table 91 Case 1z Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	50.12	3.58	60.01	0.08	0.17	39.77
Pass 3	0.00	3.24	89.73	0.13	0.26	1.95
Pass 4	87.03	68.12	86.32	0.02	1.53	2.18

Table 92 Case 1z Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.40	0.000004393	0.001184219	0.000160470	0.000232148	0.503914
01 Jul 2011 19:05:00	6.18	0.000004236	0.000473517	0.000160348	0.000231760	0.303517
02 Jul 2011 05:10:00	182.11	0.000027170	0.005040290	0.000178728	0.000299585	0.130099
02 Jul 2011 05:10:00	182.10	0.000026289	0.000517833	0.000178504	0.000298810	0.127569
02 Jul 2011 06:52:00	112.20	0.000018186	0.008896489	0.000180396	0.000295949	0.090547
02 Jul 2011 06:52:00	14.55	0.000005797	0.001217420	0.000180357	0.000291427	0.088573

Case 1aa Tables

Table 93 Case 1aa Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	**Radial**	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.124	140.955	19.665	27.11	3.50	2.14
01 Jul 2011 19:05:00	28.744	51.546	19.633	11.47	3.19	2.13
02 Jul 2011 05:10:00	50.572	601.567	59.571	63.91	5.41	8.18
02 Jul 2011 05:10:00	31.695	57.099	59.514	8.01	3.72	8.18
02 Jul 2011 06:51:00	28.932	305.089	67.432	37.81	2.74	4.40
02 Jul 2011 06:51:00	22.718	129.743	60.876	16.69	2.71	4.14

Table 94 Case 1aa Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	50.12	3.58	60.01	0.08	0.17	39.77
Pass 3	3.40	11.11	84.72	0.01	0.07	20.76
Pass 4	55.82	20.10	41.21	4.69	9.69	4.29

Table 95 Case 1aa Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.40	0.000004393	0.001184219	0.000160470	0.000232148	0.503914
01 Jul 2011 19:05:00	6.18	0.000004236	0.000473517	0.000160348	0.000231760	0.303517
02 Jul 2011 05:10:00	33.28	0.000006958	0.005075825	0.000317213	0.001023969	0.655215
02 Jul 2011 05:10:00	32.15	0.000006185	0.000775611	0.000317229	0.001023283	0.519224
02 Jul 2011 06:51:00	31.81	0.000007780	0.002532584	0.000284497	0.000829498	1.021854
02 Jul 2011 06:51:00	14.05	0.000006217	0.001488932	0.000271153	0.000749115	1.065728

Case 2 Variants

Case 2

Table 96 Case 2 Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
Pass 1	84.51	97.93	0.00	96.69	79.40	0.00
Pass 2	1.86	47.84	1.93	44.25	0.07	0.02
Pass 3	19.94	79.38	0.62	78.39	14.83	0.44
Pass 4	0.10	40.40	1.00	35.62	0.04	0.24

Table 97 Case 2 Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	**Radial**	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
01 Jul 2011 17:30:00	207.908	4,066.797	20.858	450.60	16.43	2.10
01 Jul 2011 17:30:00	32.205	84.180	20.858	14.92	3.39	2.10
01 Jul 2011 19:04:00	28.960	118.261	19.967	23.87	3.15	2.12
01 Jul 2011 19:04:00	28.422	61.690	19.581	13.31	3.15	2.12
02 Jul 2011 05:16:00	34.219	667.021	20.921	68.83	3.55	2.23
02 Jul 2011 05:16:00	27.394	137.561	20.790	14.87	3.03	2.22
02 Jul 2011 06:49:00	26.948	90.108	20.058	13.11	3.01	2.21
02 Jul 2011 06:49:00	26.920	53.700	19.858	8.44	3.01	2.21

Table 98 Case 2 Classical Element Sigma Percentages

	Semi-Major Axis	**Eccentricity**	**True Arg of Lat**	**Inclination**	**RAAN**	**Arg of Perigee**
Pass 1	90.54	66.77	97.93	0.00	0.00	0.95
Pass 2	40.38	1.00	47.84	0.08	1.89	31.72
Pass 3	38.39	20.78	79.38	0.70	0.37	32.99
Pass 4	21.20	6.46	40.41	0.62	0.61	6.46

Table 99 Case 2 Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:30:00	121.42	0.000013057	0.033908955	0.000158134	0.000173713	1.016799
01 Jul 2011 17:30:00	11.48	0.000004339	0.000701912	0.000158129	0.000173718	1.007110
01 Jul 2011 19:04:00	11.26	0.000004253	0.000986102	0.000160128	0.000165803	0.941892
01 Jul 2011 19:04:00	6.71	0.000004211	0.000514391	0.000159994	0.000162666	0.643145
02 Jul 2011 05:16:00	9.93	0.000007781	0.005556461	0.000172781	0.000169372	0.984445
02 Jul 2011 05:16:00	6.12	0.000006164	0.001145936	0.000171575	0.000168746	0.659641
02 Jul 2011 06:49:00	6.52	0.000005505	0.000750652	0.000173091	0.000160422	0.504003
02 Jul 2011 06:49:00	5.14	0.000005150	0.000447349	0.000172012	0.000159436	0.471449

Case 2a Tables

Table 100 Case 2a Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	84.51	97.93	0.00	96.69	79.40	0.00
Pass 2	3.32	58.37	1.35	46.68	0.12	0.03
Pass 3	19.83	80.44	0.48	77.05	15.60	0.40
Pass 4	0.84	43.13	0.67	35.34	1.84	0.17

Table 101 Case 2a Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:30:00	207.908	4,066.797	20.858	450.60	16.43	2.10
01 Jul 2011 17:30:00	32.205	84.180	20.858	14.92	3.39	2.10
01 Jul 2011 19:05:00	41.178	194.770	20.464	29.52	4.44	2.24
01 Jul 2011 19:05:00	39.813	81.080	20.188	15.74	4.44	2.24
02 Jul 2011 05:16:00	47.097	703.504	21.828	71.25	5.06	2.30
02 Jul 2011 05:16:00	37.756	137.635	21.723	16.36	4.27	2.29
02 Jul 2011 06:49:00	38.825	104.567	21.046	17.76	4.43	2.27
02 Jul 2011 06:49:00	38.499	59.472	20.904	11.48	4.35	2.27

Table 102 Case 2a Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.54	66.77	97.93	0.00	0.00	0.95
Pass 2	55.15	8.17	58.37	0.05	1.34	8.70
Pass 3	28.04	16.87	80.44	0.59	0.28	21.79
Pass 4	26.25	0.86	43.13	0.43	0.43	13.57

Table 103 Case 2a Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:30:00	121.42	0.000013057	0.033908955	0.000158134	0.000173713	1.016799
01 Jul 2011 17:30:00	11.48	0.000004339	0.000701912	0.000158129	0.000173718	1.007110
01 Jul 2011 19:05:00	19.47	0.000008588	0.001624690	0.000168983	0.000170096	0.604222
01 Jul 2011 19:05:00	8.73	0.000007886	0.000676335	0.000168904	0.000167809	0.551636
02 Jul 2011 05:16:00	10.38	0.000007366	0.005857535	0.000181260	0.000173718	1.151254
02 Jul 2011 05:16:00	7.47	0.000006123	0.001145988	0.000180187	0.000173230	0.900381
02 Jul 2011 06:49:00	7.79	0.000005593	0.000870644	0.000181232	0.000164626	0.708695
02 Jul 2011 06:49:00	5.74	0.000005545	0.000495169	0.000180453	0.000163918	0.612550

Case 2b Tables

Table 104 Case 2b Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
Pass 1	84.51	97.93	0.00	96.69	79.40	0.00
Pass 2	16.88	90.44	0.07	84.45	22.98	0.00
Pass 3	22.48	82.39	0.49	78.17	18.95	0.33
Pass 4	1.24	42.18	0.75	33.62	2.60	0.10

Table 105 Case 2b Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:30:00	207.908	4,066.797	20.858	450.60	16.43	2.10
01 Jul 2011 17:30:00	32.205	84.180	20.858	14.92	3.39	2.10
01 Jul 2011 19:05:00	36.294	882.776	20.478	94.06	4.44	2.23
01 Jul 2011 19:05:00	30.168	84.430	20.464	14.63	3.42	2.23
02 Jul 2011 05:17:00	36.130	681.541	21.795	68.22	3.86	2.28
02 Jul 2011 05:17:00	28.007	120.052	21.689	14.89	3.13	2.27
02 Jul 2011 06:50:00	29.359	95.501	20.970	17.53	3.36	2.24
02 Jul 2011 06:50:00	28.995	55.218	20.813	11.64	3.27	2.24

Table 106 Case 2b Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.54	66.77	97.93	0.00	0.00	0.95
Pass 2	89.46	41.07	90.44	0.00	0.07	0.25
Pass 3	25.46	16.87	82.39	0.52	0.29	26.90
Pass 4	26.04	12.15	42.18	0.36	0.53	13.33

Table 107 Case 2b Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:30:00	121.42	0.000013057	0.033908955	0.000158134	0.000173713	1.016799
01 Jul 2011 17:30:00	11.48	0.000004339	0.000701912	0.000158129	0.000173718	1.007110
01 Jul 2011 19:05:00	91.06	0.000014447	0.007358984	0.000168814	0.000169872	0.393493
01 Jul 2011 19:05:00	9.60	0.000008513	0.000703823	0.000168809	0.000169753	0.392500
02 Jul 2011 05:17:00	9.52	0.000011129	0.005665263	0.000180459	0.000172514	0.387192
02 Jul 2011 05:17:00	7.10	0.000009251	0.000997933	0.000179515	0.000172012	0.283020
02 Jul 2011 06:50:00	7.35	0.000008560	0.000793972	0.000180320	0.000162777	0.261912
02 Jul 2011 06:50:00	5.44	0.000007520	0.000459064	0.000179673	0.000161921	0.227009

Case 2c Tables

Table 108 Case 2c Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	84.51	97.93	0.00	96.69	79.40	0.00
Pass 2	2.35	63.08	1.47	50.39	0.33	0.61
Pass 3	19.93	78.22	2.93	75.73	15.25	2.56
Pass 4	0.00	42.49	3.66	34.38	0.31	2.19

Table 109 Case 2c Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:30:00	207.908	4,066.797	20.858	450.60	16.43	2.10
01 Jul 2011 17:30:00	32.205	84.180	20.858	14.92	3.39	2.10
01 Jul 2011 19:04:00	29.626	192.713	35.565	28.62	3.23	4.36
01 Jul 2011 19:04:00	28.928	71.155	35.043	14.20	3.22	4.34
02 Jul 2011 05:16:00	35.225	691.796	38.987	70.25	3.69	3.79
02 Jul 2011 05:16:00	28.205	150.663	37.846	17.05	3.13	3.70
02 Jul 2011 06:49:00	28.659	98.857	34.861	16.70	3.25	3.26
02 Jul 2011 06:49:00	28.659	56.848	33.585	10.96	3.24	3.19

Table 110 Case 2c Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.54	66.77	97.93	0.00	0.00	0.95
Pass 2	58.32	7.08	63.07	0.69	1.49	9.26
Pass 3	29.87	18.65	78.22	2.96	2.45	26.70
Pass 4	24.59	10.94	42.49	3.09	2.96	9.01

Table 111 Case 2c Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:30:00	121.42	0.000013057	0.033908955	0.000158134	0.000173713	1.016799
01 Jul 2011 17:30:00	11.48	0.000004339	0.000701912	0.000158129	0.000173718	1.007110
01 Jul 2011 19:04:00	19.30	0.000004649	0.001606907	0.000348371	0.000272550	0.947248
01 Jul 2011 19:04:00	8.04	0.000004319	0.000593357	0.000345959	0.000268483	0.859566
02 Jul 2011 05:16:00	10.16	0.000011251	0.005762867	0.000342082	0.000264607	1.257553
02 Jul 2011 05:16:00	7.13	0.000009153	0.001255006	0.000331958	0.000258132	0.921841
02 Jul 2011 06:49:00	7.42	0.000007817	0.000823525	0.000307434	0.000223981	0.750852
02 Jul 2011 06:49:00	5.59	0.000006961	0.000473595	0.000297936	0.000217352	0.683237

Case 2d Tables

Table 112 Case 2d Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	84.51	97.93	0.00	96.69	79.40	0.00
Pass 2	1.38	72.06	0.57	54.66	0.39	0.04
Pass 3	21.91	81.22	0.33	75.72	18.49	0.52
Pass 4	3.46	44.15	0.40	36.82	4.79	0.25

Table 113 Case 2d Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:30:00	207.908	4,066.797	20.858	450.60	16.43	2.10
01 Jul 2011 17:30:00	32.205	84.180	20.858	14.92	3.39	2.10
01 Jul 2011 19:05:00	61.983	329.889	22.039	41.81	6.84	2.55
01 Jul 2011 19:05:00	61.128	92.179	21.913	18.96	6.81	2.55
02 Jul 2011 05:16:00	69.532	743.607	24.302	73.84	7.63	2.49
02 Jul 2011 05:16:00	54.300	139.639	24.222	17.93	6.22	2.48
02 Jul 2011 06:49:00	55.892	119.764	23.674	21.03	6.42	2.42
02 Jul 2011 06:49:00	53.961	66.888	23.580	13.28	6.11	2.41

Table 114 Case 2d Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.54	66.77	97.93	0.00	0.00	0.95
Pass 2	71.41	3.92	72.06	0.05	0.57	0.18
Pass 3	19.57	24.85	81.22	0.64	0.16	21.53
Pass 4	29.68	9.34	44.15	0.41	0.22	16.63

Table 115 Case 2d Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:30:00	121.42	0.000013057	0.033908955	0.000158134	0.000173713	1.016799
01 Jul 2011 17:30:00	11.48	0.000004339	0.000701912	0.000158129	0.000173718	1.007110
01 Jul 2011 19:05:00	33.56	0.000014882	0.002752868	0.000193099	0.000182280	0.428466
01 Jul 2011 19:05:00	9.60	0.000014298	0.000769217	0.000193011	0.000181236	0.427684
02 Jul 2011 05:16:00	10.71	0.000014709	0.006188415	0.000203902	0.000185987	0.629000
02 Jul 2011 05:16:00	8.62	0.000011054	0.001162108	0.000202606	0.000185690	0.493574
02 Jul 2011 06:49:00	8.84	0.000010110	0.000996652	0.000202245	0.000176191	0.461332
02 Jul 2011 06:49:00	6.22	0.000009165	0.000556627	0.000201407	0.000175807	0.384599

Case 2e Tables

Table 116 Case 2e Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
Pass 1	84.51	97.93	0.00	96.69	79.40	0.00
Pass 2	39.48	95.34	0.02	92.03	48.19	0.00
Pass 3	23.21	83.49	0.66	78.52	20.79	0.51
Pass 4	0.36	38.54	1.39	30.83	1.09	0.26

Table 117 Case 2e Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	**Radial**	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
01 Jul 2011 17:30:00	207.908	4,066.797	20.858	450.60	16.43	2.10
01 Jul 2011 17:30:00	32.205	84.180	20.858	14.92	3.39	2.10
01 Jul 2011 19:05:00	51.128	1,761.219	22.169	183.96	6.73	2.53
01 Jul 2011 19:05:00	30.942	82.074	22.165	14.66	3.49	2.53
02 Jul 2011 05:18:00	37.969	651.973	24.343	64.69	4.13	2.43
02 Jul 2011 05:18:00	29.157	107.616	24.183	13.89	3.27	2.42
02 Jul 2011 06:52:00	29.742	92.703	23.104	17.20	3.37	2.39
02 Jul 2011 06:52:00	29.635	56.979	22.783	11.90	3.33	2.38

Table 118 Case 2e Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.54	66.77	97.93	0.00	0.00	0.95
Pass 2	94.86	64.06	95.34	0.00	0.01	2.26
Pass 3	22.81	17.40	83.49	0.75	0.39	27.61
Pass 4	23.66	12.17	38.54	0.71	1.06	11.61

Table 119 Case 2e Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:30:00	121.42	0.000013057	0.033908955	0.000158134	0.000173713	1.016799
01 Jul 2011 17:30:00	11.48	0.000004339	0.000701912	0.000158129	0.000173718	1.007110
01 Jul 2011 19:05:00	181.55	0.000026955	0.014677701	0.000192755	0.000181840	0.244502
01 Jul 2011 19:05:00	9.34	0.000009688	0.000683987	0.000192747	0.000181817	0.238966
02 Jul 2011 05:18:00	8.82	0.000010787	0.005408105	0.000202318	0.000183243	0.226932
02 Jul 2011 05:18:00	6.81	0.000008910	0.000892679	0.000200796	0.000182519	0.164275
02 Jul 2011 06:52:00	7.04	0.000008537	0.000769073	0.000199855	0.000171090	0.158913
02 Jul 2011 06:52:00	5.37	0.000007499	0.000472697	0.000198426	0.000169271	0.140466

Case 2f Tables

Table 120 Case 2f Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	84.51	97.93	0.00	96.69	79.40	0.00
Pass 2	4.00	74.20	1.38	61.58	2.61	1.05
Pass 3	18.01	75.92	7.24	73.26	13.79	6.83
Pass 4	0.00	42.45	6.35	33.79	0.25	4.68

Table 121 Case 2f Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:30:00	207.908	4,066.797	20.858	450.60	16.43	2.10
01 Jul 2011 17:30:00	32.205	84.180	20.858	14.92	3.39	2.10
01 Jul 2011 19:04:00	31.539	326.484	62.159	39.59	3.47	7.92
01 Jul 2011 19:04:00	30.277	84.223	61.303	15.21	3.38	7.84
02 Jul 2011 05:16:00	36.683	711.650	61.384	71.79	3.87	5.82
02 Jul 2011 05:16:00	30.076	171.397	56.940	19.20	3.34	5.42
02 Jul 2011 06:49:00	30.723	102.529	46.453	17.94	3.49	4.15
02 Jul 2011 06:49:00	30.722	59.011	43.504	11.88	3.48	3.96

Table 122 Case 2f Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.54	66.77	97.93	0.00	0.00	0.95
Pass 2	71.62	19.75	74.19	1.09	1.39	0.94
Pass 3	26.66	19.22	75.92	7.26	6.70	25.05
Pass 4	25.25	12.44	42.43	5.74	5.58	8.96

Table 123 Case 2f Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:30:00	121.42	0.000013057	0.033908955	0.000158134	0.000173713	1.016799
01 Jul 2011 17:30:00	11.48	0.000004339	0.000701912	0.000158129	0.000173718	1.007110
01 Jul 2011 19:04:00	33.31	0.000005673	0.002722336	0.000639156	0.000463326	0.963069
01 Jul 2011 19:04:00	9.45	0.000004553	0.000702538	0.000632192	0.000456889	0.954052
02 Jul 2011 05:16:00	10.29	0.000012450	0.005928308	0.000545700	0.000394798	1.374961
02 Jul 2011 05:16:00	7.54	0.000010057	0.001427547	0.000506096	0.000368343	1.030516
02 Jul 2011 06:49:00	7.76	0.000008533	0.000854092	0.000411123	0.000280265	0.831802
02 Jul 2011 06:49:00	5.80	0.000007471	0.000491668	0.000387523	0.000264633	0.757293

Case 2g Tables

Table 124 Case 2g Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	84.51	97.93	0.00	96.69	79.40	0.00
Pass 2	1.86	47.84	1.93	44.25	0.07	0.02
Pass 3	20.35	87.32	0.22	85.70	13.34	0.17
Pass 4	1.00	41.24	0.95	34.84	1.77	0.38

Table 125 Case 2g Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.54	66.77	97.93	0.00	0.00	0.95
Pass 2	40.38	1.00	47.84	0.08	1.89	31.72
Pass 3	59.64	5.91	87.32	0.27	0.13	3.80
Pass 4	24.64	0.09	41.24	0.81	0.54	11.97

Table 126 Case 2g Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:30:00	121.42	0.000013057	0.033908955	0.000158134	0.000173713	1.016799
01 Jul 2011 17:30:00	11.48	0.000004339	0.000701912	0.000158129	0.000173718	1.007110
01 Jul 2011 19:04:00	11.26	0.000004253	0.000986102	0.000160128	0.000165803	0.941892
01 Jul 2011 19:04:00	6.71	0.000004211	0.000514391	0.000159994	0.000162666	0.643145
02 Jul 2011 05:16:00	17.66	0.000007260	0.009477606	0.000176713	0.000178463	0.712681
02 Jul 2011 05:16:00	7.13	0.000006831	0.001201877	0.000176241	0.000178231	0.685588
02 Jul 2011 06:49:00	7.24	0.000006415	0.000861213	0.000177237	0.000168386	0.551305
02 Jul 2011 06:49:00	5.46	0.000006409	0.000506055	0.000175794	0.000167473	0.485307

Case 2h Tables

Table 127 Case 2h Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	84.51	97.93	0.00	96.69	79.40	0.00
Pass 2	1.86	47.84	1.93	44.25	0.07	0.02
Pass 3	75.99	97.46	0.00	97.08	66.77	0.01
Pass 4	0.83	43.48	1.26	35.22	1.85	0.48

Table 128 Case 2h Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:30:00	207.908	4,066.797	20.858	450.60	16.43	2.10
01 Jul 2011 17:30:00	32.205	84.180	20.858	14.92	3.39	2.10
01 Jul 2011 19:04:00	28.960	118.261	19.967	23.87	3.15	2.12
01 Jul 2011 19:04:00	28.422	61.690	19.581	13.31	3.15	2.12
02 Jul 2011 05:17:00	118.863	5,248.819	22.249	588.92	9.62	2.23
02 Jul 2011 05:17:00	28.544	133.481	22.248	17.21	3.20	2.23
02 Jul 2011 06:50:00	30.007	99.050	21.271	17.03	3.41	2.21
02 Jul 2011 06:50:00	29.758	55.979	21.002	11.03	3.35	2.20

Table 129 Case 2h Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.54	66.77	97.93	0.00	0.00	0.95
Pass 2	40.38	1.00	47.84	0.08	1.89	31.72
Pass 3	91.80	42.29	97.46	0.00	0.01	1.09
Pass 4	25.09	12.40	43.48	1.07	0.70	9.73

Table 130 Case 2h Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:30:00	121.42	0.000013057	0.033908955	0.000158134	0.000173713	1.016799
01 Jul 2011 17:30:00	11.48	0.000004339	0.000701912	0.000158129	0.000173718	1.007110
01 Jul 2011 19:04:00	11.26	0.000004253	0.000986102	0.000160128	0.000165803	0.941892
01 Jul 2011 19:04:00	6.71	0.000004211	0.000514391	0.000159994	0.000162666	0.643145
02 Jul 2011 05:17:00	83.48	0.000016541	0.043646996	0.000175931	0.000177577	0.212933
02 Jul 2011 05:17:00	6.85	0.000009546	0.001109960	0.000175922	0.000177558	0.210618
02 Jul 2011 06:50:00	6.81	0.000009129	0.000823792	0.000176593	0.000166869	0.207555
02 Jul 2011 06:50:00	5.10	0.000007997	0.000465568	0.000174703	0.000165702	0.187355

Case 2i Tables

Table 131 Case 2i Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	84.51	97.93	0.00	96.69	79.40	0.00
Pass 2	1.86	47.84	1.93	44.25	0.07	0.02
Pass 3	30.21	84.96	0.52	83.84	20.10	0.43
Pass 4	0.01	40.79	3.53	33.46	0.34	1.30

Table 132 Case 2i Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:30:00	207.908	4,066.797	20.858	450.60	16.43	2.10
01 Jul 2011 17:30:00	32.205	84.180	20.858	14.92	3.39	2.10
01 Jul 2011 19:04:00	28.960	118.261	19.967	23.87	3.15	2.12
01 Jul 2011 19:04:00	28.422	61.690	19.581	13.31	3.15	2.12
02 Jul 2011 05:16:00	40.863	1,126.023	48.743	123.18	3.97	2.75
02 Jul 2011 05:16:00	28.518	169.385	48.491	19.90	3.17	2.73
02 Jul 2011 06:49:00	29.145	95.885	38.023	15.74	3.29	2.41
02 Jul 2011 06:49:00	29.143	56.775	36.682	10.47	3.28	2.38

Table 133 Case 2i Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.54	66.77	97.93	0.00	0.00	0.95
Pass 2	40.38	1.00	47.84	0.08	1.89	31.72
Pass 3	2.45	0.34	30.99	9.59	17.29	0.09
Pass 4	22.74	9.16	40.78	2.94	3.00	8.83

Table 134 Case 2i Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:30:00	121.42	0.000013057	0.033908955	0.000158134	0.000173713	1.016799
01 Jul 2011 17:30:00	11.48	0.000004339	0.000701912	0.000158129	0.000173718	1.007110
01 Jul 2011 19:04:00	11.26	0.000004253	0.000986102	0.000160128	0.000165803	0.941892
01 Jul 2011 19:04:00	6.71	0.000004211	0.000514391	0.000159994	0.000162666	0.643145
02 Jul 2011 05:17:00	6.77	0.000008564	0.001409970	0.000273029	0.000361997	1.128805
02 Jul 2011 05:17:00	6.60	0.000008535	0.000973072	0.000246852	0.000299413	1.129818
02 Jul 2011 06:49:00	6.86	0.000007143	0.000798766	0.000238271	0.000276540	0.728209
02 Jul 2011 06:49:00	5.30	0.000006488	0.000472990	0.000231264	0.000268251	0.663899

Case 2j Tables

Table 135 Case 2j Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
Pass 1	84.51	97.93	0.00	96.69	79.40	0.00
Pass 2	1.86	47.84	1.93	44.25	0.07	0.02
Pass 3	20.66	91.79	0.08	90.15	12.87	0.07
Pass 4	4.19	41.06	0.60	35.97	5.13	0.49

Table 136 Case 2j Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	**Radial**	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
01 Jul 2011 17:30:00	207.908	4,066.797	20.858	450.60	16.43	2.10
01 Jul 2011 17:30:00	32.205	84.180	20.858	14.92	3.39	2.10
01 Jul 2011 19:04:00	28.960	118.261	19.967	23.87	3.15	2.12
01 Jul 2011 19:04:00	28.422	61.690	19.581	13.31	3.15	2.12
02 Jul 2011 05:16:00	101.144	1,954.867	26.010	217.24	10.51	2.29
02 Jul 2011 05:16:00	80.243	160.562	25.990	21.40	9.16	2.29
02 Jul 2011 06:49:00	73.290	122.690	24.730	19.79	8.34	2.25
02 Jul 2011 06:49:00	70.218	72.313	24.581	12.67	7.91	2.24

Table 137 Case 2j Classical Element Sigma Percentages

	Semi-Major Axis	**Eccentricity**	**True Arg of Lat**	**Inclination**	**RAAN**	**Arg of Perigee**
Pass 1	90.54	66.77	97.93	0.00	0.00	0.95
Pass 2	40.38	1.00	47.84	0.08	1.89	31.72
Pass 3	71.54	5.75	91.79	0.11	0.04	0.66
Pass 4	27.86	5.05	41.06	0.81	0.31	14.96

Table 138 Case 2j Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:30:00	121.42	0.000013057	0.033908955	0.000158134	0.000173713	1.016799
01 Jul 2011 17:30:00	11.48	0.000004339	0.000701912	0.000158129	0.000173718	1.007110
01 Jul 2011 19:04:00	11.26	0.000004253	0.000986102	0.000160128	0.000165803	0.941892
01 Jul 2011 19:04:00	6.71	0.000004211	0.000514391	0.000159994	0.000162666	0.643145
02 Jul 2011 05:16:00	30.72	0.000013624	0.016264617	0.000188102	0.000203275	0.438505
02 Jul 2011 05:16:00	8.74	0.000012841	0.001335895	0.000187895	0.000203184	0.435599
02 Jul 2011 06:49:00	8.22	0.000010903	0.001020779	0.000187384	0.000189795	0.392368
02 Jul 2011 06:49:00	5.93	0.000010352	0.000601636	0.000185871	0.000189210	0.333687

Case 2k Tables

Table 139 Case 2k Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	84.51	97.93	0.00	96.69	79.40	0.00
Pass 2	1.86	47.84	1.93	44.25	0.07	0.02
Pass 3	85.69	98.78	0.00	98.57	80.74	0.01
Pass 4	2.51	41.89	1.48	34.63	3.78	0.60

Table 140 Case 2k Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:30:00	207.908	4,066.797	20.858	450.60	16.43	2.10
01 Jul 2011 17:30:00	32.205	84.180	20.858	14.92	3.39	2.10
01 Jul 2011 19:04:00	28.960	118.261	19.967	23.87	3.15	2.12
01 Jul 2011 19:04:00	28.422	61.690	19.581	13.31	3.15	2.12
02 Jul 2011 05:18:00	216.203	10,461.850	25.957	1,172.17	18.06	2.26
02 Jul 2011 05:18:00	30.939	127.964	25.956	16.75	3.48	2.26
02 Jul 2011 06:51:00	32.728	96.853	24.362	16.94	3.72	2.21
02 Jul 2011 06:51:00	31.907	56.284	24.000	11.08	3.58	2.19

Table 141 Case 2k Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.54	66.77	97.93	0.00	0.00	0.95
Pass 2	40.38	1.00	47.84	0.08	1.89	31.72
Pass 3	95.81	67.69	98.78	0.04	0.04	1.93
Pass 4	26.32	13.52	41.89	1.39	0.87	11.10

Table 142 Case 2k Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:30:00	121.42	0.000013057	0.033908955	0.000158134	0.000173713	1.016799
01 Jul 2011 17:30:00	11.48	0.000004339	0.000701912	0.000158129	0.000173718	1.007110
01 Jul 2011 19:04:00	11.26	0.000004253	0.000986102	0.000160128	0.000165803	0.941892
01 Jul 2011 19:04:00	6.71	0.000004211	0.000514391	0.000159994	0.000162666	0.643145
02 Jul 2011 05:18:00	166.38	0.000029821	0.086845122	0.000186665	0.000201727	0.125761
02 Jul 2011 05:18:00	6.96	0.000009634	0.001062226	0.000186734	0.000201639	0.123333
02 Jul 2011 06:51:00	6.72	0.000009338	0.000804254	0.000185412	0.000185109	0.122190
02 Jul 2011 06:51:00	4.95	0.000008076	0.000467370	0.000182844	0.000183492	0.108628

Case 2l Tables

Table 143 Case 2l Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
Pass 1	84.51	97.93	0.00	96.69	79.40	0.00
Pass 2	1.86	47.84	1.93	44.25	0.07	0.02
Pass 3	44.72	87.69	0.48	87.11	30.86	0.44
Pass 4	0.03	39.90	5.55	32.50	0.41	2.51

Table 144 Case 2l Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:30:00	207.908	4,066.797	20.858	450.60	16.43	2.10
01 Jul 2011 17:30:00	32.205	84.180	20.858	14.92	3.39	2.10
01 Jul 2011 19:04:00	28.960	118.261	19.967	23.87	3.15	2.12
01 Jul 2011 19:04:00	28.422	61.690	19.581	13.31	3.15	2.12
02 Jul 2011 05:16:00	56.264	1,933.093	90.503	215.59	5.01	3.91
02 Jul 2011 05:16:00	31.103	238.015	90.068	27.78	3.47	3.89
02 Jul 2011 06:49:00	32.062	98.619	49.507	16.70	3.63	2.58
02 Jul 2011 06:49:00	32.051	59.266	46.758	11.27	3.61	2.51

Table 145 Case 2l Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.54	66.77	97.93	0.00	0.00	0.95
Pass 2	40.38	1.00	47.84	0.08	1.89	31.72
Pass 3	75.82	5.01	87.69	0.53	0.45	1.36
Pass 4	22.83	9.93	39.89	4.96	5.01	9.21

Table 146 Case 2l Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:30:00	121.42	0.000013057	0.033908955	0.000158134	0.000173713	1.016799
01 Jul 2011 17:30:00	11.48	0.000004339	0.000701912	0.000158129	0.000173718	1.007110
01 Jul 2011 19:04:00	11.26	0.000004253	0.000986102	0.000160128	0.000165803	0.941892
01 Jul 2011 19:04:00	6.71	0.000004211	0.000514391	0.000159994	0.000162666	0.643145
02 Jul 2011 05:16:00	30.59	0.000009247	0.016103149	0.000460642	0.000665431	1.034380
02 Jul 2011 05:16:00	7.40	0.000008783	0.001982374	0.000458179	0.000662450	1.020357
02 Jul 2011 06:49:00	7.02	0.000007668	0.000821533	0.000287097	0.000354128	0.814806
02 Jul 2011 06:49:00	5.41	0.000006906	0.000493789	0.000272844	0.000336375	0.739725

Case 2m Tables

Table 147 Case 2m Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
Pass 1	84.51	97.93	0.00	96.69	79.40	0.00
Pass 2	1.86	47.84	1.93	44.25	0.07	0.02
Pass 3	12.48	78.76	0.63	78.46	9.57	0.38
Pass 4	0.63	63.53	0.53	59.97	0.19	0.05

Table 148 Case 2m Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	**Radial**	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
01 Jul 2011 17:30:00	207.908	4,066.797	20.858	450.60	16.43	2.10
01 Jul 2011 17:30:00	32.205	84.180	20.858	14.92	3.39	2.10
01 Jul 2011 19:04:00	28.960	118.261	19.967	23.87	3.15	2.12
01 Jul 2011 19:04:00	28.422	61.690	19.581	13.31	3.15	2.12
02 Jul 2011 05:16:00	53.014	668.847	22.032	69.28	5.64	2.27
02 Jul 2011 05:16:00	46.396	142.072	21.894	14.92	5.10	2.26
02 Jul 2011 06:49:00	41.974	174.856	20.919	22.09	4.66	2.27
02 Jul 2011 06:49:00	41.711	63.768	20.809	8.84	4.65	2.26

Table 149 Case 2m Classical Element Sigma Percentages

	Semi-Major Axis	**Eccentricity**	**True Arg of Lat**	**Inclination**	**RAAN**	**Arg of Perigee**
Pass 1	90.54	66.77	97.93	0.00	0.00	0.95
Pass 2	40.38	1.00	47.84	0.08	1.89	31.72
Pass 3	10.90	2.64	78.76	0.66	0.38	30.43
Pass 4	53.27	0.78	63.53	0.23	0.37	13.91

Table 150 Case 2m Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:30:00	121.42	0.000013057	0.033908955	0.000158134	0.000173713	1.016799
01 Jul 2011 17:30:00	11.48	0.000004339	0.000701912	0.000158129	0.000173718	1.007110
01 Jul 2011 19:04:00	11.26	0.000004253	0.000986102	0.000160128	0.000165803	0.941892
01 Jul 2011 19:04:00	6.71	0.000004211	0.000514391	0.000159994	0.000162666	0.643145
02 Jul 2011 05:16:00	18.96	0.000008840	0.005568482	0.000173510	0.000180950	0.493991
02 Jul 2011 05:16:00	16.89	0.000008607	0.001182830	0.000172370	0.000180262	0.343674
02 Jul 2011 06:49:00	16.82	0.000007929	0.001455864	0.000174063	0.000170734	0.284440
02 Jul 2011 06:49:00	7.86	0.000007867	0.000530933	0.000173669	0.000170110	0.244887

Case 2n Tables

Table 151 Case 2n Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	84.51	97.93	0.00	96.69	79.40	0.00
Pass 2	1.86	47.84	1.93	44.25	0.07	0.02
Pass 3	7.86	78.10	0.64	77.63	14.92	0.39
Pass 4	34.17	91.92	1.34	90.66	3.64	0.03

Table 152 Case 2n Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:30:00	207.908	4,066.797	20.858	450.60	16.43	2.10
01 Jul 2011 17:30:00	32.205	84.180	20.858	14.92	3.39	2.10
01 Jul 2011 19:04:00	28.960	118.261	19.967	23.87	3.15	2.12
01 Jul 2011 19:04:00	28.422	61.690	19.581	13.31	3.15	2.12
02 Jul 2011 05:16:00	57.893	667.204	22.029	69.14	3.65	2.27
02 Jul 2011 05:16:00	53.345	146.084	21.889	15.47	3.11	2.26
02 Jul 2011 06:49:00	42.170	788.466	21.017	94.81	3.19	2.26
02 Jul 2011 06:49:00	27.761	63.746	20.735	8.85	3.07	2.26

Table 153 Case 2n Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.54	66.77	97.93	0.00	0.00	0.95
Pass 2	40.38	1.00	47.84	0.08	1.89	31.72
Pass 3	0.89	7.98	78.10	0.67	0.39	0.91
Pass 4	89.24	53.15	91.92	0.08	1.34	30.61

Table 154 Case 2n Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:30:00	121.42	0.000013057	0.033908955	0.000158134	0.000173713	1.016799
01 Jul 2011 17:30:00	11.48	0.000004339	0.000701912	0.000158129	0.000173718	1.007110
01 Jul 2011 19:04:00	11.26	0.000004253	0.000986102	0.000160128	0.000165803	0.941892
01 Jul 2011 19:04:00	6.71	0.000004211	0.000514391	0.000159994	0.000162666	0.643145
02 Jul 2011 05:16:00	91.02	0.000015921	0.005554244	0.000173480	0.000180876	0.194086
02 Jul 2011 05:16:00	90.21	0.000014651	0.001216116	0.000172323	0.000180170	0.192326
02 Jul 2011 06:49:00	82.14	0.000012791	0.006564773	0.000173886	0.000171493	0.213324
02 Jul 2011 06:49:00	8.84	0.000005992	0.000530747	0.000173746	0.000169196	0.148030

Case 2o Tables

Table 155 Case 2o Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	84.51	97.93	0.00	96.69	79.40	0.00
Pass 2	1.86	47.84	1.93	44.25	0.07	0.02
Pass 3	18.08	76.00	1.25	75.19	14.14	0.08
Pass 4	2.35	63.69	1.09	59.60	0.09	0.11

Table 156 Case 2o Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:30:00	207.908	4,066.797	20.858	450.60	16.43	2.10
01 Jul 2011 17:30:00	32.205	84.180	20.858	14.92	3.39	2.10
01 Jul 2011 19:04:00	28.960	118.261	19.967	23.87	3.15	2.12
01 Jul 2011 19:04:00	28.422	61.690	19.581	13.31	3.15	2.12
02 Jul 2011 05:16:00	35.830	667.074	44.671	68.86	3.64	3.30
02 Jul 2011 05:16:00	29.350	160.079	44.112	17.08	3.12	3.30
02 Jul 2011 06:49:00	28.482	172.780	32.402	22.04	3.10	3.16
02 Jul 2011 06:49:00	27.812	62.735	32.049	8.90	3.09	3.15

Table 157 Case 2o Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.54	66.77	97.93	0.00	0.00	0.95
Pass 2	40.38	1.00	47.84	0.08	1.89	31.72
Pass 3	9.42	19.18	76.00	0.03	1.09	29.51
Pass 4	53.14	5.26	63.69	0.02	0.92	12.61

Table 158 Case 2o Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:30:00	121.42	0.000013057	0.033908955	0.000158134	0.000173713	1.016799
01 Jul 2011 17:30:00	11.48	0.000004339	0.000701912	0.000158129	0.000173718	1.007110
01 Jul 2011 19:04:00	11.26	0.000004253	0.000986102	0.000160128	0.000165803	0.941892
01 Jul 2011 19:04:00	6.71	0.000004211	0.000514391	0.000159994	0.000162666	0.643145
02 Jul 2011 05:16:00	18.61	0.000007937	0.005556905	0.000194458	0.000402844	1.025706
02 Jul 2011 05:16:00	16.86	0.000006415	0.001333560	0.000194396	0.000398459	0.723047
02 Jul 2011 06:49:00	16.77	0.000005690	0.001439360	0.000191310	0.000304568	0.544777
02 Jul 2011 06:49:00	7.86	0.000005390	0.000522601	0.000191273	0.000301773	0.476065

Case 2p Tables

Table 159 Case 2p Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
Pass 1	84.51	97.93	0.00	96.69	79.40	0.00
Pass 2	1.86	47.84	1.93	44.25	0.07	0.02
Pass 3	10.90	76.99	0.64	78.49	9.16	0.24
Pass 4	0.70	77.06	0.41	75.81	0.68	0.00

Table 160 Case 2p Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	**Radial**	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
01 Jul 2011 17:30:00	207.908	4,066.797	20.858	450.60	16.43	2.10
01 Jul 2011 17:30:00	32.205	84.180	20.858	14.92	3.39	2.10
01 Jul 2011 19:04:00	28.960	118.261	19.967	23.87	3.15	2.12
01 Jul 2011 19:04:00	28.422	61.690	19.581	13.31	3.15	2.12
02 Jul 2011 05:16:00	87.762	673.871	25.064	70.56	9.45	2.38
02 Jul 2011 05:16:00	78.200	155.072	24.903	15.18	8.58	2.38
02 Jul 2011 06:49:00	62.947	311.825	23.269	37.56	7.01	2.41
02 Jul 2011 06:49:00	62.505	71.540	23.173	9.08	6.97	2.41

Table 161 Case 2p Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.54	66.77	97.93	0.00	0.00	0.95
Pass 2	40.38	1.00	47.84	0.08	1.89	31.72
Pass 3	4.15	0.15	76.99	0.55	0.42	24.29
Pass 4	72.50	0.02	77.06	0.07	0.34	26.78

Table 162 Case 2p Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:30:00	121.42	0.000013057	0.033908955	0.000158134	0.000173713	1.016799
01 Jul 2011 17:30:00	11.48	0.000004339	0.000701912	0.000158129	0.000173718	1.007110
01 Jul 2011 19:04:00	11.26	0.000004253	0.000986102	0.000160128	0.000165803	0.941892
01 Jul 2011 19:04:00	6.71	0.000004211	0.000514391	0.000159994	0.000162666	0.643145
02 Jul 2011 05:16:00	33.42	0.000014232	0.005607093	0.000175637	0.000211986	0.339849
02 Jul 2011 05:16:00	32.04	0.000014211	0.001290334	0.000174673	0.000211097	0.257286
02 Jul 2011 06:49:00	31.54	0.000011944	0.002594858	0.000176559	0.000198182	0.222233
02 Jul 2011 06:49:00	8.68	0.000011946	0.000595318	0.000176441	0.000197511	0.162716

Case 2q Tables

Table 163 Case 2q Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	84.51	97.93	0.00	96.69	79.40	0.00
Pass 2	1.86	47.84	1.93	44.25	0.07	0.02
Pass 3	4.41	74.75	0.69	75.69	14.34	0.25
Pass 4	49.26	95.19	3.96	94.43	10.40	0.46

Table 164 Case 2q Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:30:00	207.908	4,066.797	20.858	450.60	16.43	2.10
01 Jul 2011 17:30:00	32.205	84.180	20.858	14.92	3.39	2.10
01 Jul 2011 19:04:00	28.960	118.261	19.967	23.87	3.15	2.12
01 Jul 2011 19:04:00	28.422	61.690	19.581	13.31	3.15	2.12
02 Jul 2011 05:16:00	99.619	667.773	25.059	70.22	3.91	2.39
02 Jul 2011 05:16:00	95.228	168.625	24.886	17.07	3.35	2.38
02 Jul 2011 06:49:00	58.115	1,319.346	23.531	157.94	3.63	2.42
02 Jul 2011 06:49:00	29.487	63.499	22.598	8.80	3.26	2.41

Table 165 Case 2q Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.54	66.77	97.93	0.00	0.00	0.95
Pass 2	40.38	1.00	47.84	0.08	1.89	31.72
Pass 3	0.98	1.18	74.75	0.58	0.45	1.21
Pass 4	93.60	71.15	95.19	0.04	4.11	27.06

Table 166 Case 2q Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:30:00	121.42	0.000013057	0.033908955	0.000158134	0.000173713	1.016799
01 Jul 2011 17:30:00	11.48	0.000004339	0.000701912	0.000158129	0.000173718	1.007110
01 Jul 2011 19:04:00	11.26	0.000004253	0.000986102	0.000160128	0.000165803	0.941892
01 Jul 2011 19:04:00	6.71	0.000004211	0.000514391	0.000159994	0.000162666	0.643145
02 Jul 2011 05:16:00	181.82	0.000027699	0.005555238	0.000175572	0.000211785	0.119798
02 Jul 2011 05:16:00	180.05	0.000027371	0.001402816	0.000174558	0.000210826	0.118349
02 Jul 2011 06:49:00	137.59	0.000020381	0.010979115	0.000176181	0.000201187	0.128998
02 Jul 2011 06:49:00	8.81	0.000005881	0.000528412	0.000176112	0.000192920	0.094086

Case 2r Tables

Table 167 Case 2r Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
Pass 1	84.51	97.93	0.00	96.69	79.40	0.00
Pass 2	1.86	47.84	1.93	44.25	0.07	0.02
Pass 3	14.18	68.38	3.39	67.83	12.43	1.95
Pass 4	8.34	78.15	1.92	75.72	0.23	0.83

Table 168 Case 2r Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:30:00	207.908	4,066.797	20.858	450.60	16.43	2.10
01 Jul 2011 17:30:00	32.205	84.180	20.858	14.92	3.39	2.10
01 Jul 2011 19:04:00	28.960	118.261	19.967	23.87	3.15	2.12
01 Jul 2011 19:04:00	28.422	61.690	19.581	13.31	3.15	2.12
02 Jul 2011 05:16:00	40.277	667.235	81.668	68.93	3.87	5.35
02 Jul 2011 05:16:00	34.565	210.946	78.897	22.17	3.39	5.25
02 Jul 2011 06:49:00	32.514	307.604	41.237	37.72	3.33	3.87
02 Jul 2011 06:49:00	29.803	67.226	40.447	9.16	3.32	3.84

Table 169 Case 2r Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.54	66.77	97.93	0.00	0.00	0.95
Pass 2	40.38	1.00	47.84	0.08	1.89	31.72
Pass 3	3.02	15.21	68.38	0.68	3.28	22.71
Pass 4	72.53	6.65	78.15	0.13	1.82	26.07

Table 170 Case 2r Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:30:00	121.42	0.000013057	0.033908955	0.000158134	0.000173713	1.016799
01 Jul 2011 17:30:00	11.48	0.000004339	0.000701912	0.000158129	0.000173718	1.007110
01 Jul 2011 19:04:00	11.26	0.000004253	0.000986102	0.000160128	0.000165803	0.941892
01 Jul 2011 19:04:00	6.71	0.000004211	0.000514391	0.000159994	0.000162666	0.643145
02 Jul 2011 05:16:00	33.01	0.000008389	0.005558239	0.000248785	0.000750391	1.139777
02 Jul 2011 05:16:00	32.01	0.000007113	0.001757473	0.000247088	0.000725810	0.880969
02 Jul 2011 06:49:00	31.53	0.000006188	0.002562537	0.000207618	0.000399839	0.649276
02 Jul 2011 06:49:00	8.66	0.000005776	0.000559980	0.000207349	0.000392568	0.480006

Case 3 Variants

Case 3a Tables

Table 171 Case 3a Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	7.95	75.03	0.42	58.61	1.24	0.05
Pass 3	38.22	92.77	1.01	87.39	32.88	0.19
Pass 4	7.61	26.25	3.83	20.58	4.86	0.02

Table 172 Case 3a Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	**Radial**	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
01 Jul 2011 17:27:00.000000	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00.000000	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00.000000	36.980	222.877	20.118	33.40	3.92	2.29
01 Jul 2011 19:05:00.000000	34.041	55.656	20.033	13.83	3.87	2.29
02 Jul 2011 05:10:00.000000	69.887	792.579	22.384	83.02	7.50	2.33
02 Jul 2011 05:10:00.000000	43.175	57.309	22.159	10.47	5.03	2.33
02 Jul 2011 06:51:00.000000	27.563	92.154	21.272	16.42	3.02	2.45
02 Jul 2011 06:51:00.000000	25.465	67.960	20.457	13.04	2.87	2.45

Table 173 Case 3a Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	55.88	8.51	72.72	0.04	0.42	11.94
Pass 3	39.88	17.62	92.48	0.03	1.26	21.43
Pass 4	15.52	4.36	20.27	0.11	3.79	14.45

Table 174 Case 3a Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	20.29	0.000007046	0.001856492	0.000172165	0.000237733	0.452471
01 Jul 2011 19:05:00	8.95	0.000006447	0.000506531	0.000172093	0.000236724	0.398468
02 Jul 2011 05:10:00	12.41	0.000005597	0.006630477	0.000183927	0.000251948	1.183166
02 Jul 2011 05:10:00	7.46	0.000004611	0.000498385	0.000183870	0.000248780	0.929610
02 Jul 2011 06:51:00	7.94	0.000009691	0.000779446	0.000185636	0.000248249	0.802297
02 Jul 2011 06:51:00	6.71	0.000009269	0.000621444	0.000185437	0.000238828	0.686335

Case 3b Tables

Table 175 Case 3b Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	2.78	93.43	0.01	85.99	31.54	0.00
Pass 3	35.56	92.50	1.15	85.82	30.28	0.13
Pass 4	7.21	24.37	4.75	20.20	5.02	0.01

Table 176 Case 3b Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.290	884.868	20.131	97.71	5.71	2.29
01 Jul 2011 19:05:00	33.337	58.146	20.129	13.69	3.91	2.29
02 Jul 2011 05:12:00	57.601	768.990	22.238	81.14	6.21	2.33
02 Jul 2011 05:12:00	37.118	57.698	21.981	11.50	4.33	2.32
02 Jul 2011 06:53:00	27.989	97.952	21.318	18.00	2.99	2.44
02 Jul 2011 06:53:00	25.970	74.083	20.305	14.36	2.84	2.44

Table 177 Case 3b Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	88.23	51.42	92.83	0.00	0.01	0.11
Pass 3	40.70	3.50	92.24	0.05	1.33	19.80
Pass 4	15.21	11.50	18.98	0.07	4.75	5.82

Table 178 Case 3b Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	91.70	0.000013903	0.007389921	0.000171955	0.000237659	0.299539
01 Jul 2011 19:05:00	10.79	0.000006754	0.000530066	0.000171950	0.000237635	0.299196
02 Jul 2011 05:12:00	12.23	0.000008485	0.006423775	0.000183203	0.000250455	0.372997
02 Jul 2011 05:12:00	7.25	0.000008188	0.000498724	0.000183109	0.000247123	0.299145
02 Jul 2011 06:53:00	7.68	0.000007724	0.000817052	0.000185003	0.000248836	0.433550
02 Jul 2011 06:53:00	6.51	0.000006836	0.000661964	0.000184873	0.000237020	0.408326

Case 3c Tables

Table 179 Case 3c Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	9.05	74.97	0.34	61.10	1.36	0.03
Pass 3	39.88	92.61	0.62	87.66	34.07	0.00
Pass 4	9.42	25.32	6.65	20.40	6.55	2.35

Table 180 Case 3c Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	**Radial**	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.638	221.437	23.917	32.80	3.64	5.24
01 Jul 2011 19:05:00	31.504	55.430	23.834	12.76	3.59	5.24
02 Jul 2011 05:10:00	59.650	771.206	41.209	81.25	6.36	3.91
02 Jul 2011 05:10:00	35.859	56.975	40.952	10.02	4.19	3.91
02 Jul 2011 06:51:00	26.057	90.677	27.825	15.88	2.81	4.99
02 Jul 2011 06:51:00	23.603	67.720	25.973	12.64	2.63	4.88

Table 181 Case 3c Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	55.66	0.64	71.69	0.03	0.34	14.07
Pass 3	42.47	12.98	92.33	0.11	1.18	29.45
Pass 4	15.32	6.59	16.95	2.68	6.48	6.03

Table 182 Case 3c Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	20.16	0.000004958	0.001848063	0.000391982	0.000287778	0.505735
01 Jul 2011 19:05:00	8.94	0.000004926	0.000523107	0.000391858	0.000286797	0.434553
02 Jul 2011 05:10:00	12.28	0.000010153	0.006461249	0.000397132	0.000307002	0.748537
02 Jul 2011 05:10:00	7.06	0.000008835	0.000495588	0.000396678	0.000303372	0.528117
02 Jul 2011 06:51:00	7.61	0.000009654	0.000768516	0.000388856	0.000296269	1.233494
02 Jul 2011 06:51:00	6.45	0.000009018	0.000638229	0.000378450	0.000277058	1.159119

Case 3d Tables

Table 183 Case 3d Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	2.91	83.02	0.14	61.77	0.74	0.02
Pass 3	36.80	93.01	0.76	85.75	32.29	0.12
Pass 4	6.35	27.18	3.85	19.76	3.69	0.11

Table 184 Case 3d Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	43.504	344.871	20.508	44.84	4.87	2.71
01 Jul 2011 19:05:00	42.238	58.546	20.480	17.14	4.84	2.71
02 Jul 2011 05:10:00	94.803	853.386	24.825	88.55	10.31	2.52
02 Jul 2011 05:10:00	59.919	59.677	24.636	12.62	6.98	2.52
02 Jul 2011 06:51:00	30.738	97.235	22.221	18.70	3.43	2.80
02 Jul 2011 06:51:00	28.785	70.807	21.367	15.00	3.31	2.80

Table 185 Case 3d Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	70.22	8.04	81.46	0.01	0.14	1.58
Pass 3	32.93	28.40	92.71	0.03	1.07	15.56
Pass 4	15.40	5.00	21.01	0.26	3.81	14.05

Table 186 Case 3d Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	34.16	0.000012900	0.002878489	0.000203275	0.000242939	0.396245
01 Jul 2011 19:05:00	10.17	0.000011863	0.000533697	0.000203246	0.000242602	0.389985
02 Jul 2011 05:10:00	13.00	0.000014493	0.007131763	0.000213430	0.000257643	0.682253
02 Jul 2011 05:10:00	8.72	0.000010377	0.000519591	0.000213359	0.000254876	0.576100
02 Jul 2011 06:51:00	8.79	0.000012300	0.000824288	0.000214678	0.000255392	0.345028
02 Jul 2011 06:51:00	7.44	0.000011686	0.000651135	0.000214112	0.000245650	0.296557

Case 3e Tables

Table 187 Case 3e Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	6.38	96.70	0.21	92.67	59.68	0.00
Pass 3	33.96	92.48	1.02	85.66	29.77	0.12

Table 188 Case 3e Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	35.336	1,756.130	20.630	189.69	9.61	2.70
01 Jul 2011 19:05:00	33.081	57.898	20.587	13.90	3.87	2.70
02 Jul 2011 05:13:00	59.571	762.962	24.567	80.23	6.49	2.51
02 Jul 2011 05:13:00	39.343	57.366	24.317	11.50	4.56	2.50

Table 189 Case 3e Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	94.09	72.44	96.39	0.00	0.21	0.80
Pass 3	40.24	2.50	92.19	0.05	1.36	19.15

Table 190 Case 3e Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	182.66	0.000026607	0.014667107	0.000202855	0.000243142	0.213882
01 Jul 2011 19:05:00	10.79	0.000007333	0.000529338	0.000202854	0.000242633	0.212161
02 Jul 2011 05:13:00	11.77	0.000007672	0.006361302	0.000211905	0.000254943	0.231772
02 Jul 2011 05:13:00	7.04	0.000007480	0.000497075	0.000211792	0.000251479	0.187394

Case 3f Tables

Table 191 Case 3f Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	**Intrack**	**Crosstrack**	**Radial**	**Intrack**	**Crosstrack**
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	4.65	83.16	0.11	69.02	1.29	0.03
Pass 3	36.23	92.46	0.71	86.46	30.38	0.14
Pass 4	11.41	24.68	12.51	18.47	8.35	8.42

Table 192 Case 3f Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.890	342.829	33.019	43.27	3.92	9.81
01 Jul 2011 19:05:00	33.266	57.723	32.982	13.40	3.87	9.81
02 Jul 2011 05:10:00	61.394	777.841	73.466	82.37	6.59	6.77
02 Jul 2011 05:10:00	39.153	58.665	72.945	11.15	4.59	6.76
02 Jul 2011 06:51:00	26.942	93.504	40.381	17.22	2.90	8.64
02 Jul 2011 06:51:00	23.868	70.426	35.330	14.04	2.66	7.91

Table 193 Case 3f Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	70.11	13.66	79.25	0.03	0.11	4.31
Pass 3	41.22	9.08	92.17	0.35	1.19	25.31
Pass 4	14.29	5.81	11.87	8.77	12.25	6.74

Table 194 Case 3f Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	34.01	0.000006275	0.002869464	0.000732982	0.000405540	0.509824
01 Jul 2011 19:05:00	10.16	0.000005418	0.000595539	0.000732752	0.000405089	0.487865
02 Jul 2011 05:10:00	12.67	0.000011102	0.006531166	0.000734965	0.000435264	0.786480
02 Jul 2011 05:10:00	7.45	0.000010094	0.000511487	0.000732370	0.000430103	0.587419
02 Jul 2011 06:51:00	7.92	0.000011032	0.000798759	0.000676162	0.000397391	1.353228
02 Jul 2011 06:51:00	6.79	0.000010391	0.000703939	0.000616872	0.000348694	1.262009

Case 3g Tables

Table 195 Case 3g Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.05	67.46	0.79	57.82	8.78	0.09
Pass 3	23.00	94.91	0.66	91.98	16.94	0.39
Pass 4	8.96	25.46	4.94	19.19	6.79	0.06

Table 196 Case 3g Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.553	161.858	19.986	28.47	3.54	2.14
01 Jul 2011 19:05:00	29.354	52.664	19.827	12.01	3.23	2.13
02 Jul 2011 05:10:00	75.178	1,189.563	22.953	129.89	7.97	2.27
02 Jul 2011 05:10:00	57.889	60.527	22.800	10.42	6.62	2.26
02 Jul 2011 06:51:00	35.409	89.237	22.240	15.31	3.92	2.34
02 Jul 2011 06:51:00	32.235	66.519	21.141	12.38	3.65	2.34

Table 197 Case 3g Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	43.37	3.75	64.40	0.08	0.80	28.91
Pass 3	62.44	2.41	94.75	0.01	1.03	8.92
Pass 4	12.68	2.74	18.80	0.24	4.86	5.49

Table 198 Case 3g Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.51	0.000004433	0.001344295	0.000160480	0.000235944	0.504361
01 Jul 2011 19:05:00	7.08	0.000004267	0.000478542	0.000160354	0.000234048	0.358528
02 Jul 2011 05:10:00	18.90	0.000006710	0.009933189	0.000176239	0.000263044	0.660891
02 Jul 2011 05:10:00	7.10	0.000006549	0.000521859	0.000176228	0.000260346	0.601953
02 Jul 2011 06:51:00	7.48	0.000005350	0.000751809	0.000178063	0.000259433	1.077510
02 Jul 2011 06:51:00	6.53	0.000005203	0.000610496	0.000177640	0.000246818	1.018393

Case 3h Tables

Table 199 Case 3h Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.05	67.46	0.79	57.82	8.78	0.09
Pass 3	49.62	98.86	1.88	97.99	29.83	4.83
Pass 4	5.20	19.28	6.22	14.86	3.63	0.09

Table 200 Case 3h Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.553	161.858	19.986	28.47	3.54	2.14
01 Jul 2011 19:05:00	29.354	52.664	19.827	12.01	3.23	2.13
02 Jul 2011 05:11:00	96.199	5,216.994	23.211	586.22	7.95	2.36
02 Jul 2011 05:11:00	48.461	59.346	22.775	11.77	5.58	2.25
02 Jul 2011 06:53:00	27.037	90.886	22.234	16.83	2.95	2.34
02 Jul 2011 06:53:00	25.630	73.366	20.850	14.33	2.84	2.34

Table 201 Case 3h Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	43.37	3.75	64.40	0.08	0.80	28.91
Pass 3	92.13	35.86	98.83	1.15	4.99	0.38
Pass 4	10.82	6.38	13.72	0.21	6.18	0.18

Table 202 Case 3h Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.51	0.000004433	0.001344295	0.000160480	0.000235944	0.504361
01 Jul 2011 19:05:00	7.08	0.000004267	0.000478542	0.000160354	0.000234048	0.358528
02 Jul 2011 05:11:00	85.54	0.000016382	0.043477420	0.000177528	0.000273451	0.224548
02 Jul 2011 05:11:00	6.73	0.000010507	0.000509678	0.000175492	0.000259804	0.223699
02 Jul 2011 06:53:00	7.02	0.000011012	0.000756539	0.000177356	0.000259987	0.237179
02 Jul 2011 06:53:00	6.26	0.000010310	0.000652761	0.000176988	0.000243915	0.236743

Case 3i Tables

Table 203 Case 3i Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.05	67.46	0.79	57.82	8.78	0.09
Pass 3	30.83	95.01	0.17	91.94	22.64	0.40
Pass 4	8.78	20.74	12.62	14.86	6.37	3.93

Table 204 Case 3i Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.553	161.858	19.986	28.47	3.54	2.14
01 Jul 2011 19:05:00	29.354	52.664	19.827	12.01	3.23	2.13
02 Jul 2011 05:10:00	60.306	1,178.597	50.448	128.78	6.24	2.27
02 Jul 2011 05:10:00	41.713	58.831	50.363	10.39	4.82	2.26
02 Jul 2011 06:51:00	26.465	87.413	42.698	15.20	2.89	3.04
02 Jul 2011 06:51:00	24.141	69.282	37.309	12.94	2.71	2.92

Table 205 Case 3i Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	43.37	3.75	64.40	0.08	0.80	28.91
Pass 3	63.64	1.97	94.36	0.04	0.28	14.55
Pass 4	11.21	2.81	6.49	5.40	12.59	6.97

Table 206 Case 3i Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.51	0.000004433	0.001344295	0.000160480	0.000235944	0.504361
01 Jul 2011 19:05:00	7.08	0.000004267	0.000478542	0.000160354	0.000234048	0.358528
02 Jul 2011 05:10:00	18.73	0.000008679	0.009853016	0.000261922	0.000524163	0.693992
02 Jul 2011 05:10:00	6.81	0.000008508	0.000555653	0.000261829	0.000522684	0.593047
02 Jul 2011 06:51:00	7.31	0.000009857	0.000786044	0.000250853	0.000481692	1.124113
02 Jul 2011 06:51:00	6.49	0.000009580	0.000735034	0.000237314	0.000421041	1.045755

Case 3j Tables

Table 207 Case 3j Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.05	67.46	0.79	57.82	8.78	0.09
Pass 3	14.30	96.48	0.48	94.55	8.62	0.82
Pass 4	11.16	26.04	6.67	18.43	9.05	0.32

Table 208 Case 3j Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.553	161.858	19.986	28.47	3.54	2.14
01 Jul 2011 19:05:00	29.354	52.664	19.827	12.01	3.23	2.13
02 Jul 2011 05:10:00	111.689	1,969.390	26.832	219.25	11.89	2.27
02 Jul 2011 05:10:00	95.716	69.322	26.703	11.95	10.86	2.26
02 Jul 2011 06:51:00	43.681	91.632	25.604	16.25	4.86	2.42
02 Jul 2011 06:51:00	38.808	67.772	23.895	13.25	4.42	2.42

Table 209 Case 3j Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	43.37	3.75	64.40	0.08	0.80	28.91
Pass 3	74.92	6.06	96.37	0.09	1.01	0.34
Pass 4	10.84	1.79	17.71	0.75	6.58	6.76

Table 210 Case 3j Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.51	0.000004433	0.001344295	0.000160480	0.000235944	0.504361
01 Jul 2011 19:05:00	7.08	0.000004267	0.000478542	0.000160354	0.000234048	0.358528
02 Jul 2011 05:10:00	31.94	0.000012907	0.016419436	0.000186187	0.000298618	0.469659
02 Jul 2011 05:10:00	8.01	0.000012125	0.000595739	0.000186023	0.000295598	0.471239
02 Jul 2011 06:51:00	7.76	0.000007228	0.000772161	0.000187668	0.000295133	0.527016
02 Jul 2011 06:51:00	6.92	0.000007098	0.000635437	0.000186265	0.000275700	0.491398

Case 3k Tables

Table 211 Case 3k Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.05	67.46	0.79	57.82	8.78	0.09
Pass 3	70.51	99.42	4.87	98.96	56.77	13.38

Table 212 Case 3k Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.553	161.858	19.986	28.47	3.54	2.14
01 Jul 2011 19:05:00	29.354	52.664	19.827	12.01	3.23	2.13
02 Jul 2011 05:13:00	161.030	10,402.001	27.927	1,167.73	12.60	2.58
02 Jul 2011 05:13:00	47.495	60.736	26.568	12.09	5.45	2.24

Table 213 Case 3k Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	43.37	3.75	64.40	0.08	0.80	28.91
Pass 3	96.21	62.81	99.40	3.68	11.45	1.87

Table 214 Case 3k Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.51	0.000004433	0.001344295	0.000160480	0.000235944	0.504361
01 Jul 2011 19:05:00	7.08	0.000004267	0.000478542	0.000160354	0.000234048	0.358528
02 Jul 2011 05:13:00	171.45	0.000029140	0.086551552	0.000191608	0.000331715	0.138828
02 Jul 2011 05:13:00	6.49	0.000010838	0.000523297	0.000184554	0.000293735	0.136232

Case 3l Tables

Table 215 Case 3l Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.05	67.46	0.79	57.82	8.78	0.09
Pass 3	28.74	96.81	0.05	94.69	16.65	0.83
Pass 4	12.21	16.08	24.43	9.02	9.96	14.27

Table 216 Case 3l Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.553	161.858	19.986	28.47	3.54	2.14
01 Jul 2011 19:05:00	29.354	52.664	19.827	12.01	3.23	2.13
02 Jul 2011 05:10:00	66.881	1,952.503	93.771	217.70	6.60	2.28
02 Jul 2011 05:10:00	47.660	62.381	93.720	11.56	5.50	2.26
02 Jul 2011 06:51:00	29.022	87.942	67.609	16.00	3.20	4.11
02 Jul 2011 06:51:00	25.478	73.800	51.092	14.56	2.88	3.53

Table 217 Case 3l Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	43.37	3.75	64.40	0.08	0.80	28.91
Pass 3	77.89	1.72	95.69	0.09	0.09	3.53
Pass 4	6.84	0.86	0.15	16.67	24.41	7.23

Table 218 Case 3l Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.51	0.000004433	0.001344295	0.000160480	0.000235944	0.504361
01 Jul 2011 19:05:00	7.08	0.000004267	0.000478542	0.000160354	0.000234048	0.358528
02 Jul 2011 05:10:00	31.72	0.000009627	0.016309689	0.000429604	0.000955162	0.710886
02 Jul 2011 05:10:00	7.01	0.000009462	0.000703637	0.000429219	0.000954325	0.685782
02 Jul 2011 06:51:00	7.41	0.000011084	0.000880556	0.000356157	0.000757279	1.285573
02 Jul 2011 06:51:00	6.91	0.000010989	0.000879263	0.000296770	0.000572391	1.192597

Case 3m Tables

Table 219 Case 3m Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.05	67.46	0.79	57.82	8.78	0.09
Pass 3	37.85	92.53	1.05	89.47	33.24	0.24
Pass 4	9.80	47.62	2.46	46.08	3.38	0.00

Table 220 Case 3m Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.553	161.858	19.986	28.47	3.54	2.14
01 Jul 2011 19:05:00	29.354	52.664	19.827	12.01	3.23	2.13
02 Jul 2011 05:10:00	64.528	762.778	22.042	79.70	6.87	2.37
02 Jul 2011 05:10:00	40.106	57.012	21.811	8.39	4.59	2.36
02 Jul 2011 06:51:00	37.683	173.426	22.112	22.72	4.09	2.35
02 Jul 2011 06:51:00	33.989	90.843	21.569	12.25	3.95	2.35

Table 221 Case 3m Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	43.37	3.75	64.40	0.08	0.80	28.91
Pass 3	14.62	8.62	92.20	0.02	1.21	37.13
Pass 4	38.63	8.12	43.03	0.05	2.41	7.33

Table 222 Case 3m Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.51	0.000004433	0.001344295	0.000160480	0.000235944	0.504361
01 Jul 2011 19:05:00	7.08	0.000004267	0.000478542	0.000160354	0.000234048	0.358528
02 Jul 2011 05:10:00	19.98	0.000009142	0.006384043	0.000174399	0.000264622	0.446952
02 Jul 2011 05:10:00	17.06	0.000008353	0.000498142	0.000174368	0.000261431	0.280991
02 Jul 2011 06:51:00	17.28	0.000007311	0.001447801	0.000176406	0.000260697	0.479988
02 Jul 2011 06:51:00	10.60	0.000006717	0.000824881	0.000176321	0.000254420	0.444785

Case 3n Tables

Table 223 Case 3n Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.05	67.46	0.79	57.82	8.78	0.09
Pass 3	39.77	92.57	1.05	88.24	33.37	0.24
Pass 4	44.16	86.55	0.64	85.70	0.23	0.03

Table 224 Case 3n Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.553	161.858	19.986	28.47	3.54	2.14
01 Jul 2011 19:05:00	29.354	52.664	19.827	12.01	3.23	2.13
02 Jul 2011 05:10:00	61.000	762.791	22.040	79.52	6.79	2.37
02 Jul 2011 05:10:00	36.738	56.651	21.810	9.35	4.53	2.36
02 Jul 2011 06:51:00	43.231	750.846	22.022	91.14	2.84	2.35
02 Jul 2011 06:51:00	24.139	100.952	21.881	13.03	2.83	2.34

Table 225 Case 3n Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	43.37	3.75	64.40	0.08	0.80	28.91
Pass 3	0.40	15.85	92.25	0.02	1.21	4.06
Pass 4	84.70	54.34	85.34	0.07	0.60	0.17

Table 226 Case 3n Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.51	0.000004433	0.001344295	0.000160480	0.000235944	0.504361
01 Jul 2011 19:05:00	7.08	0.000004267	0.000478542	0.000160354	0.000234048	0.358528
02 Jul 2011 05:10:00	91.32	0.000016614	0.006384913	0.000174349	0.000264528	0.203656
02 Jul 2011 05:10:00	90.96	0.000013981	0.000494974	0.000174317	0.000261336	0.195381
02 Jul 2011 06:51:00	78.42	0.000013457	0.006241714	0.000176244	0.000259641	0.165169
02 Jul 2011 06:51:00	12.00	0.000006145	0.000915259	0.000176117	0.000258095	0.164893

Case 3o Tables

Table 227 Case 3o Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.05	67.46	0.79	57.82	8.78	0.09
Pass 3	46.78	92.62	0.37	90.06	41.45	0.12
Pass 4	12.06	43.33	6.89	40.78	3.08	2.05

Table 228 Case 3o Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.553	161.858	19.986	28.47	3.54	2.14
01 Jul 2011 19:05:00	29.354	52.664	19.827	12.01	3.23	2.13
02 Jul 2011 05:10:00	58.246	762.492	35.142	79.47	6.16	4.54
02 Jul 2011 05:10:00	30.996	56.248	35.012	7.90	3.60	4.54
02 Jul 2011 06:51:00	27.333	172.891	42.464	22.43	2.86	3.16
02 Jul 2011 06:51:00	24.036	97.974	39.539	13.28	2.77	3.10

Table 229 Case 3o Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	43.37	3.75	64.40	0.08	0.80	28.91
Pass 3	12.72	27.45	91.04	0.01	0.30	36.91
Pass 4	36.96	8.85	30.39	1.24	6.84	2.37

Table 230 Case 3o Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.51	0.000004433	0.001344295	0.000160480	0.000235944	0.504361
01 Jul 2011 19:05:00	7.08	0.000004267	0.000478542	0.000160354	0.000234048	0.358528
02 Jul 2011 05:10:00	19.51	0.000008477	0.006391983	0.000217974	0.000556573	0.707552
02 Jul 2011 05:10:00	17.03	0.000006150	0.000572751	0.000218003	0.000554923	0.446426
02 Jul 2011 06:51:00	17.22	0.000007034	0.001467402	0.000217249	0.000518691	1.028489
02 Jul 2011 06:51:00	10.86	0.000006411	0.001021474	0.000214557	0.000483223	1.004103

Case 3p Tables

Table 231 Case 3p Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.05	67.46	0.79	57.82	8.78	0.09
Pass 3	25.44	92.12	0.92	87.67	22.08	0.20
Pass 4	8.46	65.26	1.51	65.17	0.59	0.01

Table 232 Case 3p Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.553	161.858	19.986	28.47	3.54	2.14
01 Jul 2011 19:05:00	29.354	52.664	19.827	12.01	3.23	2.13
02 Jul 2011 05:10:00	80.893	763.583	23.595	80.40	8.75	2.65
02 Jul 2011 05:10:00	60.311	60.199	23.379	9.92	6.82	2.64
02 Jul 2011 06:51:00	48.693	308.276	25.268	38.15	5.34	2.44
02 Jul 2011 06:51:00	44.574	107.103	24.886	13.29	5.30	2.44

Table 233 Case 3p Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	43.37	3.75	64.40	0.08	0.80	28.91
Pass 3	5.48	1.23	91.68	0.01	0.92	31.81
Pass 4	58.01	2.28	61.51	0.00	1.48	22.40

Table 234 Case 3p Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.51	0.000004433	0.001344295	0.000160480	0.000235944	0.504361
01 Jul 2011 19:05:00	7.08	0.000004267	0.000478542	0.000160354	0.000234048	0.358528
02 Jul 2011 05:10:00	34.13	0.000014245	0.006389033	0.000178985	0.000304353	0.334443
02 Jul 2011 05:10:00	32.26	0.000014069	0.000531530	0.000178961	0.000301540	0.228062
02 Jul 2011 06:51:00	32.13	0.000008985	0.002566837	0.000181063	0.000300940	0.321769
02 Jul 2011 06:51:00	13.49	0.000008780	0.000988018	0.000181056	0.000296496	0.249690

Case 3q Tables

Table 235 Case 3q Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.05	67.46	0.79	57.82	8.78	0.09
Pass 3	26.75	92.30	0.92	83.82	21.42	0.19
Pass 4	58.86	88.09	1.35	87.73	0.10	0.01

Table 236 Case 3q Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.553	161.858	19.986	28.47	3.54	2.14
01 Jul 2011 19:05:00	29.354	52.664	19.827	12.01	3.23	2.13
02 Jul 2011 05:10:00	69.793	763.718	23.593	79.78	8.49	2.65
02 Jul 2011 05:10:00	51.125	58.797	23.375	12.91	6.67	2.64
02 Jul 2011 06:52:00	62.416	1,140.282	25.199	138.11	3.03	2.42
02 Jul 2011 06:52:00	25.678	135.770	24.860	16.94	3.03	2.42

Table 237 Case 3q Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	43.37	3.75	64.40	0.08	0.80	28.91
Pass 3	0.03	6.21	91.87	0.01	0.93	0.71
Pass 4	87.00	67.03	87.06	0.03	1.31	1.37

Table 238 Case 3q Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.51	0.000004433	0.001344295	0.000160480	0.000235944	0.504361
01 Jul 2011 19:05:00	7.08	0.000004267	0.000478542	0.000160354	0.000234048	0.358528
02 Jul 2011 05:10:00	182.15	0.000028077	0.006391660	0.000178875	0.000304093	0.133209
02 Jul 2011 05:10:00	182.10	0.000026334	0.000519338	0.000178849	0.000301275	0.132265
02 Jul 2011 06:52:00	119.14	0.000019038	0.009463348	0.000180742	0.000298449	0.101140
02 Jul 2011 06:52:00	15.49	0.000006276	0.001224463	0.000180696	0.000294531	0.099758

Case 3r Tables

Table 239 Case 3r Pos/Vel Sigma Percentages

	Position Sigma Percentages			Velocity Sigma Percentages		
	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
Pass 1	85.31	97.50	1.62	96.17	78.13	0.55
Pass 2	15.05	67.46	0.79	57.82	8.78	0.09
Pass 3	44.97	92.49	0.15	89.72	39.50	0.09
Pass 4	21.03	57.64	9.57	56.03	2.15	5.93

Table 240 Case 3r Pos/Vel Sigma Magnitudes

	Position Sigmas (m)			Velocity Sigmas (cm/s)		
Date Time (UTCG)	Radial	Intrack	Crosstrack	Radial	Intrack	Crosstrack
01 Jul 2011 17:27:00	208.047	4,008.540	21.098	446.38	16.53	2.12
01 Jul 2011 17:27:00	30.562	100.329	20.757	17.11	3.61	2.11
01 Jul 2011 19:05:00	34.553	161.858	19.986	28.47	3.54	2.14
01 Jul 2011 19:05:00	29.354	52.664	19.827	12.01	3.23	2.13
02 Jul 2011 05:10:00	59.135	762.543	59.648	79.50	6.29	8.19
02 Jul 2011 05:10:00	32.545	57.303	59.557	8.17	3.80	8.18
02 Jul 2011 06:51:00	32.469	309.735	68.977	38.36	3.14	4.47
02 Jul 2011 06:51:00	25.641	131.203	62.379	16.86	3.07	4.20

Table 241 Case 3r Classical Element Sigma Percentages

	Semi-Major Axis	Eccentricity	True Arg of Lat	Inclination	RAAN	Arg of Perigee
Pass 1	90.00	64.88	97.59	0.17	1.91	0.85
Pass 2	43.37	3.75	64.40	0.08	0.80	28.91
Pass 3	3.99	24.45	87.90	0.00	0.13	31.09
Pass 4	53.67	17.87	41.17	4.76	9.54	0.13

Table 242 Case 3r Classical Element Sigma Magnitudes

Date Time (UTCG)	Semi-Major Axis (m)	Eccentricity	True Arg Lat (°)	Inclination (°)	RAAN (°)	Arg of Perigee (°)
01 Jul 2011 17:27:00	120.81	0.000013382	0.033487714	0.000158452	0.000250164	0.523305
01 Jul 2011 17:27:00	12.08	0.000004700	0.000805431	0.000158177	0.000245377	0.518834
01 Jul 2011 19:05:00	12.51	0.000004433	0.001344295	0.000160480	0.000235944	0.504361
01 Jul 2011 19:05:00	7.08	0.000004267	0.000478542	0.000160354	0.000234048	0.358528
02 Jul 2011 05:10:00	33.55	0.000008895	0.006419727	0.000317366	0.001025220	0.762145
02 Jul 2011 05:10:00	32.21	0.000006720	0.000776473	0.000317362	0.001023850	0.525169
02 Jul 2011 06:51:00	31.92	0.000008083	0.002574560	0.000288131	0.000848487	1.140825
02 Jul 2011 06:51:00	14.79	0.000006639	0.001514645	0.000274408	0.000767564	1.139314

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14. ABSTRACT
The purpose of this research is to characterize the performance of the optimal sequential filter used in ODTK with a maneuvering satellite. Specifically, this thesis sought to characterize the performance using two scenarios: performance with a maneuver in between passes and performance with a limited number of measurements. The performance of the filter is evaluated by analyzing the covariance values generated during the orbit estimation process. Larger covariance values signify reduced performance of the filter. Several variables for the maneuvering satellite are used, including the maneuver direction and the maneuver magnitude. The time of the maneuver is also varied, which creates a short or long drift time in between passes. With sufficient data after a maneuver (about three passes) the ODTK filter is able to provide a good orbit estimate for the satellite. However, without at least three passes to gather new observations, the filter does not perform well.

15. SUBJECT TERMS
Orbit determination, orbit estimation, satellite maneuver, sequential filter

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